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General Equilibrium, Markets, Macroeconomics and Money in a Laboratory Experimental Environment

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Abstract

This paper reports on the use of laboratory experimental techniques to create relatively complete economic systems. The creation of these market systems reflects a first attempt to explore the nature of inherently interdependent environments, to assess the ability of simultaneous equations equilibrium models like the classical static general competitive equilibrium model, and to predict aspects of system behaviors. In addition, the impact of the quantity of a fiat money was studied. The economies were successfully created. Classical models capture much of what was observed.

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1 Introduction

The research[1] reported here reflects an attempt to create many of the essential features of a complete (general equilibrium/macro) economic system in the context of a laboratory environment. Newly developed experimental technologies bring closer the possibilities of studying the behavior of complicated and interdependent systems of markets. The operation of multiple markets has been explored in several studies.[2] However, the interdependence of production costs, input prices, output demand, output prices, income and fiat money has not been studied. The experiments reported here represent the first attempt to apply the technologies to that task.

The questions posed are both methodological and scientific. The methodological questions involve open questions about the uses of experimental procedures and technology in the creation of such an economy. The timing of production and consumption is important. The methods of inducing preferences involve new experimental procedural issues. The role of inventories, the procedures for dealing with bankruptcies and/or mistakes (typos), as well as the rules for beginning and ending the experiment all involve open methodological issues. The training of people involves many issues. Operational questions abound concerning the proper way to define variables especially in the application of macroeconomic concepts like gross national product, inflation and employment. The execution of the experiments require decisions on all of these complicated issues. In this context, one contribution of the study is the development of an experimental environment for the execution and study of phenomena that is characterized by such complexity.

The scientific issues begin with very basic questions. Does the "circular flow" property of economic models work? This is not a trivial question because of the simultaneous

[1]Funding of the research, supplied by the National Science Foundation, The Lynde and Harry Bradley Foundation, and the Caltech Laboratory for Experimental Economics and Political Science, is gratefully acknowledged. Peng Lian wishes to acknowledge the support of the Harvard/MIT Research Training Group in Political Economy. Participants at several lectures and workshops have made useful comments. These include UCLA (Jacob Marshak lecture 1990) and USC (1990). We wish to add a special acknowledgment to the referees who extended themselves far beyond what might be expected, and provided many suggestions that substantially changed the paper.

[2]Perhaps the most complex system of multiple markets studied to date is found in Plott (1988). Goodfellow and Plott (1990) study derived demand in a nonlinear environment. Neither study contains the complex and simultaneous interaction studied here.

equation features of the model as opposed to the market price formation and possibly nonequilibrium behavior of the economy. As viewed through the lenses of models, input prices and output prices are simultaneously determined thereby giving the system a property of internal consistency. The model suggests that the actions of individual agents will be coordinated in a decentralized way by the use of a fiat money. It is not exactly obvious how or if this will really come about in any real system, even when the system is a relatively simple laboratory economy. The first priority is a "proof of principle" regarding this basic issue.

Given that the study gets past the very basic issue of whether such a decentralized market system can function as an economy, more refined questions can be posed. Does the static Walrasian (Arrow/Debreu) general equilibrium model work in any sense at all? Is the model useful as a "benchmark" or "approximation" of behavior? This is clearly a nontrivial question. Even such basic features of an economy like the budget balance equations or profit maximization equations utilize the idea that prices have small (possibly zero) variance, but that property of small variance need not exist in an actual economy, especially one in which initial trades might be nowhere near the equilibrium values of related models. In addition, the Arrow/Debreu model provides many predictions such as price ratios, output levels, incomes, etc. In summary, the static general equilibrium model is an equilibrium model. As the mathematical model is applied here, it is also a static model in which expectations of future events play no role in decisions. The research here explores the predictive capability of this model in a market setting where there exists no apriori reason to expect equilibration. Clearly most of the basic assumptions of the static model are not satisfied in these economies so if the economies evolve "as if" the assumptions were satisfied, it might be surprising to some observers.

Once an entire economy is functioning it is natural to view its operation with the use of macroeconomic concepts. Do prices stabilize, cycle or explode? The Walrasian model says nothing at all about absolute price levels in economies with fiat money. Does the velocity of money circulation (transaction velocity and/or money demand velocity) appear to be a constant across time and economies? Is full employment attained? Does the quantity of money effect prices (absolute and/or relative) or real economic activities? All of these questions are very basic and need to be answered before the more refined questions of modern theories can be applied and tested. The real questions being posed at this stage are can an economy be created in a laboratory and if so what are its prominent features relative to the classical ideas about how economies work?

The paper is organized as follows. Section 2 contains a complete description of the economies that were created. Section 3 outlines the models and some of the major predictions that can be derived from the models when they are applied in a natural way to the economies outlined in Section 2. The statistical methodology is introduced in Section 4. Section 5 outlines the results and Section 6 contains a summary of conclusions.

2.The System Description

This section is divided into four subsections. In subsection 2.1 the basic economy is described. Subsection 2.2 describes the parameters and organization of the experiment, the experimental procedures and the experimental design are provided in Subsections 2.3 and 2.4, respectively.

2.1 The General Economic Environment

The economy is best described with the help of the classical circular flow model contained in Figure 1. The economy consists of two types of agents, consumers and producers, and the economy consists of two types of goods called X and Y. For consumers the world looks as follows. Consumer preferences reflect a desire for both X and Y. Each period they have an endowment of ten units of Y but they have no endowment of X. Thus, in order to obtain X it is necessary to sell Y for fiat money (francs) and then use the francs to buy X. For ease of exposition we will call X the output or consumption good and we will call Y labor. Of course, such labels were not used with subjects. All trades were subject to cash in advance constraints.

Producers have the capacity to use the labor Y as a productive input for X and producers also have a desire to consume Y as services but they have no preferences for X. Producers are also given (nonlinear) production functions that give them the ability to transform units of Y into units X. With the exception of the very first period in which the economy started going, producers were given endowments of neither X nor Y. Thus producers had to acquire Y on the market, use some Y to produce X which could be sold for fiat money, francs. The money could be used to purchase more Y, some of which could be consumed in order to obtain rewards (US dollars) for the period. The only endowment given to producers was (fiat) cash on hand and also three units of X at the very beginning of the experiment.

The economy operated for a series of trading periods. The very first period each consumer was given an endowment of fiat cash called francs. Typically, this was the only cash that ever entered the system. Each period consumers were given a fresh endowment of Y (ten units per consumer). In essence this is like an endowment of time each day. Fresh endowments of Y given to consumers each period were the only source of resources for the economy after the first period.

The experiment ended with the following procedure. One period before the end, the end is announced. At the end, all fiat money (francs) was converted to real values (X and Y) using the average price that existed during the final period. Thus agents had no incentive to avoid holding cash as the end of the world approached and the classical backward induction problems that lead to a zero value of money should have not been expected to occur.

In summary, the economy looked like one with two goods, labor and output. Labor could be used as a service or as a productive input for a constant nonlinear technology. Consumers were endowed each period with a constant supply of time which could be sold as labor or consumed as "leisure". Producers had a constant technology which used labor as the sole input to produce X, the only output. Producers utility functions depended upon the service of labor alone which could be purchased from the profits of X production. That is, labor could be used as either a productive factor or as a service. Unless some action was taken externally by the experimenter (for example, experiments in series 3), the money supply was constant. Trades were cash in advance.

A financial section was also necessary. Because of the nature of cash in advance constraints a possibility existed that a cash flow bind could occur. Two bond markets were created and all agents were endowed with the capacity to borrow money by selling bonds in the bond markets. Bonds paid a fixed number of francs with certainty to the holder of a specific date. Bonds had one-period lives with one type of bond coming due at the end of the period in which it was sold and the other type of bond coming due at the first mid-period after its sale. Bankruptcy was made impractical by the existence of larger fines (in dollars) for anyone who fails to acquire enough cash (francs) to cover a bond when it was due.

2.2 Specific Parameters and Organization

The choice of parameters reflects several considerations. First, in the parameters used, the consumers preferences are (additively) separable in time. That means that, the value of consumption each period is independent of consumption in the past. In addition, the utility functions and production functions were based on functions that are strictly concave with an eye to make the static Walrasian equilibrium unique and stable. Specifically, consumers had the utility function given in Table 1. The table shows the use of dollar values to induce preferences on an otherwise abstract X and Y space. It shows both the total dollar (utility) values from "consumption" and the marginals. The continuous approximation of this table is

$$\begin{aligned} \text{DollarPayoff} &= U(X,Y) = \alpha\psi(X,Y), && (1)\\ \text{where } \psi(X,Y) &= 144X - X^2 + 640Y - 32Y^2 - 3200 \text{ and} && (2)\\ \alpha &= .5 \text{ if } \psi(X,Y) \geq 0; \\ \alpha &= .25 \text{ if } \psi(X,Y) < 0. \end{aligned}$$

This transformation was used to reduce the subjects' exposure to losses. It was felt that unrealistic potential losses would reduce the credibility that losses would be enforced.

The cost of this procedure is a loss of concavity of the payoff function. If individuals attempt to maximize single period payoffs then the transformation will not effect induced preferences. If individuals attempt to maximize payoffs over the course of the experiment subject to constraint that losses never occur in any period then the transformation will not influence preferences. However, if individuals are willing to undertake periodic losses they can find a dynamic strategy that gives a better monetary return than the sum of static maximums. Individuals were not trained to look for the dynamic path and the model below assumes that they myopically look only to the current period payoff.

Producers were given both production functions and utility functions. The production function table is shown as Table 2. As can be seen, the first unit of Y used in production has a marginal product of 5 units of X. Marginal product of Y falls to 3 with the second unit of Y and it is zero after the third unit of Y.[3] The continuous approximation of this function is

$$X = f(Y_p) = 6Y_p - Y_p^2. \tag{3}$$

The utility function that was used for producers is given as Table 3. The first Y consumed is worth 160 cents. After the third Y is consumed producers have a constant "marginal utility" of Y of 100 cents per unit. The continuous approximation is

$$\begin{aligned} \phi(Y_c) &= 170Y_c - 10Y_c^2, \text{ if } 1 \leq Y_c \leq 3; \\ &= 120 + 100Y_c, \text{ if } Y_c \geq 4. \end{aligned} \tag{4}$$

In all experiments the number of consumers equaled the number of producers. The utility functions and production functions are such that the price ratio predicted by the general competitive equilibrium model would remain the same if the total number of agents changes while keeping the number of consumers and producers equal to each other.

Unconsumed inventories of X and Y carried forward from period to period. In this sense the commodities had the physical properties of assets rather than services. It was as though consumers use their leisure to produce a product on a one-unit-for-one-unit bases. This product could either be used as a productive input or it could be consumed. Consumed units of X or Y disappeared from existence in the experiment and created a dollar payoff for the consuming agent to be held in account as utility until the experiment was over and subjects were paid.

Cash balances in francs carried over from period to period. In all experiments except the final two, system cash was constant throughout the experiment. At the beginning

[3]In retrospect we would prefer to have used a production function in which the marginal product was one for units following the third. Zero marginal product means that the "aggregate supply" becomes vertical and this decreases the possibility that "overproduction" might be observed.

of period 1 each agent was given an amount of cash in francs. This initial endowment was the same for all agents. For each agent cash on hand at the beginning of a period equaled cash on hand at the end of the previous period. Thus if an agent wanted to make purchases early in a period, sufficient cash on hand would have to be planned at the end of the previous period and "held overnight". The only exceptions were the experiments in series 3 in which cash on hand at the beginning of a period was augmented by a formula that was unknown to the subject. In periods four through eleven, the cash simply appeared unexpectedly in the subject's cash holdings for the subject's use.

If a subject ended a period with no cash then in order to buy anything, something must be sold first. Bids to buy units could not be tendered unless the agent had enough cash on hand to cover the transaction. Theoretically, this cash-in-advance constraint on all transactions[4] could cause problems. Suppose a producer used all cash on hand to purchase Y which was then consumed. Without cash no more Y could be purchased and this agent could produce no more X and therefore be out of the economy. The existence of the bond markets provided agents with an opportunity to escape this bind. Thus the financial markets played a potentially important role in putting the cash in the right hands.

Each producer was given an initial endowment of three units of X at the beginning of the first period of the experiment. After this period no further endowments were given to producers. This one-time endowment was created to avoid another box that theory suggests might exist. If no X exists then the market for X cannot open and producers have no information about the potential value of producing X. The initial small inventories were intended to provide a riskless means of initiating trade in the market.

All markets were organized by the multiple unit double auction process.[5] The process operated over a local area network. Each agent was located at a computer. All bids and asks appeared on the screen. Only the highest bid and lowest ask that had been tendered since the previous contract were on the screen at any one time. A history of the last 19 transactions in each market was accessible. The computer executed trades and transferred inventories to reflect transactions. Producers were able to use the computer to transform units of Y held in inventory to units of X according to the production function. Such transformations could be made at any time during a period. Similarly the computer allowed both consumers and producers to make consumption decisions. The mechanics of this type of market are described in Plott (1991). The programs are available upon request along with programs that serve as training sessions for subjects.

[4]A technical exception exists. An agent could tender bids in more than one market. If all bids are accepted the agent's cash holdings could go negative. This happened very seldomly and the policy called for dollar fines for the existence of negative cash balances, and a requirement to sell such items as necessary to cover the amount.

[5]For the details of the trading rules see Plott and Gray (1990).

2.3 Experimental Procedures

Subjects were drawn from two groups. One was a set of graduate students (all were from the People's Republic of China) in science and engineering at California Institute of Technology. A second group were high school students who were attending a summer science orientation program at Caltech. The use of such strikingly different subjects was interpreted as an advantage which helped to control for possible difficulties that could be caused by subject characteristics.

Subjects were recruited by the announcement of an invitation to participate in a "decisionmaking experiment." They were told they would be paid in US currency and that the amount depended upon the decisions they made. All experimental markets were computerized. Subjects were given training on the computers by going to the Caltech laboratory and going through a computerized instructional package.[6] This instructional package requires from 30 minutes to one hour. They were given $ 5.00 for going through the instructions which was added to whatever they earned from the experiment.

A time was designated for the experiment. Subjects, once assembled for the first time, were randomly assigned to be a consumer or producer. If the experiment involved experienced subjects an attempt was made to have all subjects be the same type of agent as their previous experience. The instructions contained in Appendix A were read. All forms and examples in the instructions were reproduced on the chalkboard. This procedure was followed during both series 2 and series 3 except the instructions moved much faster because subjects were experienced.

The instructions consist of seven sections. The first section demonstrates how to read payoff tables and complete record sheets. The chalkboard was used to publicly demonstrate the examples. The section on endowments was supplemented by a request that they examine their computer screen and check the amounts displayed on it. The section on how the system works and the section on "Time and the end of the experiment" were read very slowly.

After the section on borrowing money subjects were advised *not* to use the bond markets unless necessary and/or when they had sufficient experience to understand how such markets worked. This admonition against use was thought to be necessary because pilot experiments suggested that subjects would have difficulty understanding that a bond sold was borrowed money and that the face amount of the bond had to be repaid. During the first series of experiments use of the bond markets required the active intervention of the experimenters. Subjects tended to not understand how to borrow money when

[6]This package demonstrates how the keys work and it also demonstrates the rules of the markets. The instructional package ends with a program which allows subjects to participate in a market with robot bidders that behave with a large random component. They are told that the purpose is to give practice with the machines and enable them to get the machine to do quickly what they want it to do.

they needed to. Subjects also needed to be reminded about the rules governing bonds when they borrowed money or loaned money. Occasionally, for example, a subject might mistakenly *buy* a bond for 120 francs thinking he/she was borrowing 120 francs for which he/she needed to only repay 100 and instead had loaned 120 francs and would be repaid 100. Confusion like this seldom occurred in series 2 or 3.

The final part of the instructions involved a technical review of the use of the computer for purposes of production and consumption. In series 1 it was important that the producers realize that their capacity to produce was refreshed every period. It was also important to emphasize to all agents that all transformations involving consumption must be made *before* a period ends, otherwise the units remain unconsumed in inventory and are carried over to the next period.

A questionnaire contained in the instructions was answered at the end of the instruction period to make sure that consumers understood how to read their payoff table, and producers knew how to read their production schedule as well as the payoff table. The answers were checked. Common problems were answered publicly. Questions prompted by the questionnaire were also repeated and answered publicly when appropriate.

The first two periods of all experiments in series 1 were 14 minutes. The time was reduced to 12 minutes in period 3 and finally to 10 minutes for all remaining periods. The experimenter circulated continuously during the periods of series 1 experiments. Almost all accounting entries were checked. Subjects were frequently asked to check their location in the payoff table. They were also asked to check the history screen to see if they were aware of all trades they had made. Any subject was free to ask questions of an instructional nature or technical nature. Subjects were warned that typos were not valid contracts and that they should yell "typo" if they made or saw one. Once identified, typos were corrected. If a subject had quickly "grabbed" a typo the experimenter facilitated the reverse trade. Typos were usually obvious involving errors that could severely damage or even bankrupt a subject.

2.4 Experimental Design

The experiments can be categorized into three related series. The overall experimental design is summarized in Table 4. The experiments are indexed by the date of the experiment. Technically speaking two experiments were conducted in addition to those used, but the data from these two are not used or counted. One was a pilot experiment (071990) and the other (073190) involved a machine breakdown and data errors. Series 1 experiments were identical except for the number of subjects and the subject pool. This series served two purposes. First it gave us a baseline on what might be expected in a general equilibrium experiment. Secondly, the series trained subjects who were used in the next two series. The use of primarily high school students might strike some as odd because of the likelihood that they would be less capable of making economic judgments than more mature people. As it turned out this choice of subjects strengthens the major results because the results tend to be confirming and not disconfirming of the economic models.

The second series provided a check on two features of the previous experiments. As will be seen, all experiments in series 1 had a tendency toward inflation throughout the whole experiment. The question posed for series 2 is whether or not the inflation is related to subjects learning about the economy and trading technology and thereby becoming better money managers throughout the experiment. Since series 2 involved only experienced subjects fewer problems caused by confusion, accounting, mistakes, etc., should be present. In addition the money supply was varied across experiments in series 2. For the four experiments the money supply was 1000 francs per agent, 500 francs/agent, 250 francs/agent, and 2000 francs/agent, respectively. This enables us to observe whether or not the level of a constant money supply has an influence on the economy.

The third series involved only very experienced agents. The series allowed us to observe the behavior of the system in the presence of uncertain monetary increases.[7] The money supply was fixed for three periods in order to let the system equilibrate somewhat. The money supply then increased exponentially until it reached the same level that existed in series 1 and one experiment in series 2, that is the money supply began at 250 francs/agent for the first three periods. It was then increased at a rate of about 18.9 for 8 periods to a level of 1000 francs/agent after which it changed no more.[8] Thus a comparison can be made between the behavior of an economy that has had a fixed money supply and an economy that reached the same level of money supply through a rapid and uncertain monetary expansion.[9]

3 Models and Predictions

Two different types of models are employed to analyze the behavior of the economies.

[7]For the third series the following statement was added to instructions. "A *possibility* exists that from time to time you will be given additional cash. *If* you are given any in some period then it will be added to your cash on hand automatically before the period begins. The amount can differ across people and across periods. If you are not given any additional, your cash on hand simply remains."

[8]Total cash per person in periods 1 thru 16 was: 250, 250, 250, 297, 353, 420, 500, 594, 706, 840, 1000, 1000, 1000, 1000, 1000, 1000, to end.

[9]A suggestion for future experimental work would be to create a third consumption commodity. A unit of this commodity would be a lottery, e.g., a 0.5 probability to win a dollar, to be played at the end of the experiment. Units of the lottery could be bought and sold in francs. The experimenter could then influence the money supply by purchase and sale of this special commodity. In a sense the experimenter could conduct open market operations.

The first is the static classical general equilibrium model that rests upon the assumption of a competitive equilibrium. Application of the static model will proceed on the assumption that individuals have no beliefs of an uncertain or dynamic nature and in particular have no expectation about inflation. The questions to be posed are the degrees to which the economies act *as if* the assumptions of this model are satisfied. The second type of model is a macroeconomic, aggregative approach to the analysis of the system. The model is used more for measurement and descriptive purposes in these economies than it is for predictions because these economies do not have many of the complicating features (international trade, technical change, capital investment, population change etc.) that provide a challenge for modern macroeconomic models.

3.1 The Static General Competitive Equilibrium

The static general competitive equilibrium comes from the following principles. Consumers maximize utilities subject to budget constraints. That is each consumer acquires an allocation that solves the problem.

$$\max_{X_{ic},Y_{ic}} U(X_{ic},Y_{ic}) = \alpha(144X_{ic} - X_{ic}^2 + 640Y_{ic} - 32Y_{ic}^2 - 3200) \tag{5}$$

$$\text{subject to } \; P_X X_{ic} + P_Y Y_{ic} = P_Y 10, \tag{6}$$

where X_{ic} and Y_{ic} are respectively the amounts of X and Y consumed by consumer $i(i = 1, \ldots, N)$ respectively.

Producers maximize utilities subject to technical and budget constraints. That is each producer chooses levels of production and consumption that solves

$$\begin{aligned} \max_{Y_{jc},Y_{jp}} \phi(Y_{jc}) &= 170Y_{jc} - 10Y_{jc}^2 && (7)\\ \text{subject to } f(Y_{jp}) &= 6Y_{jp} - Y_{jp}^2 \text{ and} && (8)\\ P_Y Y_{jc} &= P_X f(Y_{jp}) - P_Y Y_{jp}. && (9) \end{aligned}$$

where Y_{jc} and Y_{jp} are respectively the amounts of Y consumed and the amount of Y used in the production of X by producer $j(j = 1, \ldots, N)$.

The competitive equilibrium equations can be solved for the equilibrium price ratio $\frac{P_Y}{P_X}$, the consumption levels of consumers, consumer utilities or payoffs, the consumption levels of producers, the amount of Y used in production, the amount of X produced, producer utilities or payoffs. For the continuous approximation the solutions at the individual level of analysis are: demand for X and supply of Y by individual consumers

$$X_{ic} = \frac{72}{1 + 32(\frac{P_X}{P_Y})^2}, \tag{10}$$

$$Y_{is} = \frac{72\frac{P_Y}{P_X}}{32 + \left(\frac{P_Y}{P_X}\right)^2}, \tag{11}$$

and, the supply of X and demand for Y by individual producers

$$X_{jp} = \frac{36\left(\frac{P_X}{P_Y}\right)^2 - 1}{4\left(\frac{P_X}{P_Y}\right)^2}, \tag{12}$$

$$Y_{id} = \frac{36 - \left(\frac{P_Y}{P_X}\right)^2}{4\frac{P_Y}{P_X}}. \tag{13}$$

Table 5 contains the numerical predictions of the static general competitive equilibrium model. Figure 2 illustrates the solution for a one consumer and one producer economy. As can be seen the parameters were chosen such that the per capita predictions were independent of the number of agents. The equilibrium price ratio $\frac{P_Y}{P_X} = 2$. At equilibrium consumers sell 4 of their 10 units of Y leaving 6 for consumption. The income is used to purchase 8 units of X that are all consumed. Producers maximize profits by purchasing 2 units of Y that are used to make 8 units of X. The profits are then used to buy 2 units of Y for consumption purposes.

Individuals have no induced time preference and in the static equilibrium there are no cash constraints. The model as specified above contains no explicit account of the need for money or its use. Borrowing money imposes a cost in terms of a slight risk, given the technology of the bond market. Therefore, strictly speaking, interest rates should be zero and the bond markets should not open according to the static competitive equilibrium model.

3.2 System Efficiency and Production Efficiency Measures

The measurement of system efficiency encounters all of the problems that classical welfare economics encountered with the attempts to measure social welfare. All of the impossibility results can be applied to the laboratory economies with the same ease that they can be applied to naturally occurring economies. The appropriate response in both cases is to scale back any expectations about what any system of measurement can do.

The measure chosen for this study is the total income in dollars that agents receive. If agents do not trade, they receive zero dollar income and the system would have an efficiency of 0. If trade generates the maximum possible total dollar income the efficiency is 100 %. i.e.,

$$\text{system efficiency} = E_s = \frac{\text{Real Total Income in Dollars}}{\text{Maximum Possible Total Income in Dollars}}. \tag{14}$$

In these experiments the parameters for all experiments were conveniently chosen such that the static competitive equilibrium maximizes the total dollar income for all subjects. Thus the dollar income becomes a welfare measure with which efficiency can be assessed. The dollar income can also be used as a measure of how closely the behavior of the system approximates the static competitive equilibrium model.

The second measurement of efficiency concerns the relationship between aggregate outputs and the production frontier. Production efficiency is defined as the ratio of the real total output to the maximum potential total output which can be produced by using the real total input. Specifically

$$\text{production efficiency} = E_p = \frac{\sum_{j=1}^{N} X_{jp}}{X_p^*(\sum_{j=1}^{N} Y_{jp})}. \tag{15}$$

X_{jp} is the amount of X produced by producer j, and $X_p^*(\sum_{j=1}^{N} Y_{jp})$ is the maximum X that could be produced when $\sum_{j=1}^{N} Y_{jp}$ is used in production. Productive efficiency is substantially effected by the relative use of inputs across producers.

4 Statistical Methodology

A single statistical model is used to analyze most of the experimental market data. This model assumes that for any particular dependent variable, each experiment may start from a different origin but that all markets will experience adjustment, as described by a common functional form. Formally, the model was introduced for application in experiments in Noussair, Plott, and Riezman (1994). It is,

$$y_{it} = B_{11}D_1\frac{1}{t} + \ldots + B_{1j}D_j\frac{1}{t} + \ldots + B_{1K}D_K\frac{1}{t} + B_2\frac{t-1}{t} + u_{it}, \tag{16}$$

where i is the index of the experiment. Dj is a dummy variable that takes value 1 if $i = j$ and value 0 otherwise. t is time measured in terms of the number of market periods in the experiment. K is the number of experiments. u_{it} is a random error term that is distributed normally with mean 0.

The model is an attempt to answer questions about the direction of convergence as well as asymptotic behavior. It allows for the possibility that variables may take different values at the start of different experiments. The terms B_{1i} measure these different origins of the data for the different experiments. The model then assumes that the experiments are converging to a common value. Notice that if $t = 1$ then the value of the dependent variable equals to B_{1i} for experiment i. As t gets large the weight of B_{1j} is small because $\frac{1}{t}$ approaches zero while the weight of B_2 is large because $\frac{t-1}{t}$ approaches one. Thus, the weight of the end of the experimental session is on the common term B_2.

Thus the model can be used to test the hypothesis that the data are converging to the predictions of various models by testing whether or not the estimates of B_2 are significantly different from the predictions of the models. If the B_2 term is not significantly different from a model's prediction, we say that the variable is *strongly converging* to the prediction. In addition, the term "*weak convergence*" is used when the common value of the final data, as measured by B_2, is closer to the model's prediction than is the estimate of the start of the data, as measured by B_{1j}.

5 Results

An initial impression of the behaviors of these economies might be useful. One can be obtained from a study of Figure 3. This figure contains a time series of contract prices in the two principal markets (input and output) for experiment 072490. The vertical axis measures price and the horizontal axis measures time in seconds. The vertical lines are the ends and beginning of periods. Each dot represents a contract that could be for one or more units.

Prices in both the input and output markets begin at about the same low level. Inflation can be seen taking place in both markets for the first three periods. By period 5 the prices in the markets have clearly separated. The input price is about twice the level of the output price as is predicted by the general competitive equilibrium model. A slight inflation continues until the end of the experiment. Price variances are tending to fall over time, except for the final period. The bond markets are seldom active and thus are not shown. Market volumes and allocations (not shown) are converging toward the static competitive equilibrium quantities, as will be discussed later. This convergence together with the price increases over the experiment suggests that velocity of money is increasing but at a decreasing rate. In the sections that follow, the generality of such impressions will be made clear.

The results are discussed in three major sections. The first section reviews the data in relation to the static general equilibrium model. The second section is focused on models of partial equilibrium and individual choice behavior. The third section reviews the data in relation to macroeconomics measurements. In all sections the motivation for the questions posed and the interpretation of the results are discussed along with the technical issues. Because so many variables are operating in the experiments and because so many questions can be posed, this form of organizing the data seems to be best.

5.1 Static General Competitive Equilibrium

The first questions to be examined are those that are related to the behavior of the system as a whole. These are related to the overall ability of the economy to function at all and the ability of the static general competitive equilibrium model to predict.

Perhaps the most basic issue is the existence of any sense of order in a world that is as complex as the one that we have created. The substantial complexity of a fully functioning economy with its many interdependencies leads naturally to questions about its capacity to operate, the time scale involved, the coordination of activities, etc. No one really knows much about the total experience in the economy in which we live because the knowledge of the underlying parameters is spread across all of the agents and is thus not known in any one place where testing of theories could take place. The order we observe in the world could be the result of customs, sociological phenomena, accident, legal conventions, regulation, biological or natural selection, etc. We cannot really reject the theory that we are actually involved in a chaotic system in which the long cycles and jumps are unknown to us because of the lack of an appropriate time scale and the lack of data. The first result reflects an attempt to pose the broad issues about the order in an economic system and begins with a hypothesis we shall call the lack of order hypothesis.

The lack of order hypothesis. A completely unplanned economy will experience disequilibria, cycles, instability, coordination failures and other features that result from the interdependencies of the system. Gains from trade will not be realized and the circular flow found in microeconomics textbooks will not be operative.

Result 1. The lack of order hypothesis can be rejected.

Support. The support for the result is derived from five observations about the various aspects of the hypothesis. First, system efficiencies (defined by (14)) are not zeroes as would be the case if the system experienced complete breakdown. In fact, the system efficiencies reported in Table 6 are consistently large with the median efficiency of 88.9 % per period. This means that the system is substantially able to facilitate gains from exchange. Secondly, production efficiencies (defined by (15)) are virtually 100% as reported in Table 7. In other words, Y used in production and X produced are on the production frontier. Figure 2 demonstrates the technical relationship between inputs and outputs. A level of 100 % means that input use is efficiently distributed across the producers. Even though the production functions are nonlinear, the pricing process coordinates producer to produce efficiently in the technical sense.

The third fact that bears on the validity of the result is the variability in the allocations and whether or not they are experiencing some sort of randomness as opposed to a non oscillating pattern. As it turns out, the variability of allocations ($X_{ic}, Y_{ic}, Y_{jc}, Y_{jp}$, X_{jp}, INV_X, and INV_Y) as measured by the standard deviations decreases over time . That is, the standard deviations of the individual consumer's consumption (X_{ic}, Y_{ic}), individual producer consumption and production (Y_{ic}, Y_{jp}, X_{jp}), and inventory holdings ($\text{INV}_X, \text{INV}_Y$) get smaller with replications of the economy over time. Formally, this phenomenon is captured by the following statistical argument and with data presented in Table 8. Pool the data across all experiments and let the standard deviation of allocations in the early periods, i.e. 1, 2, ...,T-4 be σ_1^2 and the standard deviation of the late periods (T-3, T-2, T-1) be σ_2^2. The final period data are not used. The number of observations for early periods is $n = 92$ and for the three late periods (T-3, T-2, and T-1) the number of observations is $m = 33$. The hypothesis

$$H_0 : \sigma_1^2 \leq \sigma_2^2$$

can be rejected for X_{ic}, Y_{ic}, Y_{jp}, X_{jp} and INV_X at the $p < 0.01$ level. For producer consumption of Y and inventory holdings of Y, INV_Y, the variances decrease from early to late periods but the decreases are not significantly different from zero. The conclusion is that the variability of allocations decreases with time.

The fourth fact that supports the result is that the variability of the price ratio goes down over time. The same test as in the paragraph above is used to show that the sample standard deviation for price ratio is lower in later periods at significance level 0.01. The final observation that supports the result uses the same test to show that the variances of the change of absolute prices decrease over time. Pool across all experiments as done for allocations, earlier periods being 1, 2, 3, .., T-4 and late periods being T-3, T-2, T-1. A significant decrease in price variance exists for both the price of X and the price of Y. The conclusion is supported. □

The patterns reported in the support of Result 1 lead naturally to questions about the reason for the patterns and in particular about the accuracy of the Arrow/Debreu model of static general equilibrium. The next result says that the system that we are studying is not one that has equilibrated perfectly at the static competitive equilibrium. That is, the classical competitive equilibrium model can be rejected. Of course, such a result is not surprising since the model cannot ordinarily be statistically confirmed in even much simpler environments. However, a formal statement of this baseline is necessary because several of the results reported in the sections that follow are in support of the model. So, with the obvious out of the way, the analysis can proceed to more interesting aspects of the behavior of the system.

Result 2. In a strong statistical sense the static competitive equilibrium model can be rejected.

Support. First, system efficiencies (see definition (14)) are consistently less than 100% and since the competitive model predicts 100% efficiency it can be rejected. In Table 6, all average system efficiencies are less than 94% and for seven out of the eleven experiments average system efficiencies are less than 90%. Secondly, all quantities differ from those predicted by competitive equilibrium model in a statistical sense. Estimates of the parameters of the statistical model for all nine experiments in series 1 and 2 are given in Table 9. Each variable is estimated separately. We exclude the first and the last periods for each experiment so there are 86 observations for each variable. The standard errors are corrected for heteroscedasticity using White's (1980) covariance matrix estimator, and are in parentheses. As can be seen in Table 9, except the price ratio, all estimates of B_2 are significantly different from predictions of the model. Thus in a strong sense (strong convergence), the competitive equilibrium model can be rejected. □

As was mentioned above, the fact that the system does not immediately converge to the general equilibrium is not particularly surprising. The questions of substantial interest are whether or not the system is equilibrating as one might expect and where and why the static competitive equilibrium model errors. The next result is fundamental because it says that the data are weakly converging to the model's predictions.

Result 3. Convergence of allocations and convergence of the price ratio are in the direction of the static general competitive equilibrium in a weak sense. Convergence of the price ratio is to the static competitive equilibrium in the strong sense.

Support. The price ratio $\frac{P_Y}{P_X}$ is converging to the static competitive equilibrium in the strong sense as can be seen in Table 9. The estimate of B_2 is 1.97, which is not significantly different from the prediction of the competitive model of 2.00. For each of the other microeconomic variables listed as dependent variables in Table 9, comparing B_{1j} terms with the B_2 term, we find that each B_2 term is closer to the model prediction than most of its corresponding B_{1j} terms. For instance, the common term (B_2) is 6.92 for X_{ic}, the per capita consumption of X,[10] which is closer to the model prediction 8.00 than its corresponding B_{1j} terms for eight times in the nine experiments. That is to say, except 072390, each of the other eight experiments in series 1 and 2 reveals a weak converging process of the per capita consumption of X. Similarly, the Y consumed per consumer (Y_{ic}), Y consumed per producer (Y_{jc}), Y used in production per producer (Y_{jp}), X inventory per person held at the end of a period (INV$_X$), and Y inventory per person held at the end of a period (INV$_Y$) weakly converge to the model predictions (under an assumption of zero inflation) for six, six, seven, seven, and five times in the nine experiments respectively. Although for variables other than the price ratio, the common terms are closer to the model's predictions than their corresponding B_{1j} terms for most, but not all, of the time, we still consider it as weak convergence to the predictions of the static general equilibrium model. □

5.2 Partial Equilibrium Models

The analysis now moves to a less aggregated set of issues. What can be said about the behavior of individual markets and individual agents? From Table 9 it is clear that both

[10]Since X consumed per consumer in the second period tended to be much larger than those in the first, third and fourth periods for most of the nine experiments, the initial three units of X to each producer are most likely to be consumed in the second period, thus we deducted 3 from the value of X_{ic} in the second period for each experiment to reflect the true convergence pattern of X_{ic}.

the output market and the input market are equilibrating but neither has equilibrated at the static general equilibrium magnitudes. The results in this section present the data in less summary form than in Table 9 in order to illustrate aspects of the disequilibrium that exists. The fourth result is focused on the input market and the fifth result is about the output market. Results six and seven are the results of even less aggregated analysis and focus on the individual consumers and producers, respectively.

Because the theoretical demand and supply of Y depend only on the price ratio of output prices to input prices within the underlying static general competitive equilibrium model, the model can be used to compute a partial equilibrium model for the Y market. This has been done in Figures 4 and 5 which illustrate the supply and demand for the input and output as a function of the ratio of prices. The functional forms are given in equations (11) and (13) for the input and in (10) and (12) for the output.

The ratio of average output price to average input price and the associated period volume for the early periods of each experiment are shown on Figure 4-a (the top panel) and the later periods are shown in Figure 4-b (the bottom panel). The data in the figure gives three impressions. The first two can be inferred from Table 9; that is firstly, the input market is not in a partial equilibrium, and secondly, the movements of the prices and quantities in the input market are in the direction of the partial equilibrium. The third impression is that an excess demand for the input exists at the market prices. Individuals are not responding to supply enough to fully equate marginal rates of substitution to market prices. These three impressions of the data are captured by Result 4 and Result 6.

Result 4. The input market is in disequilibrium. The market volume is always less than both the theoretical quantity demanded and the theoretical quantity supplied. The movement is in the direction of the partial equilibrium.

Support. Observe the data presented in Figures 4a and 4b, and notice that the per agent quantities always lie to the left of both the demand curve and the supply curve. Thus, relative to the actual market volume, both excess demand and excess supply exist simultaneously. On average this is true in early periods as well as late periods as shown in the figures. The impression is shown by a more rigorous test. The average price ratio and the market volume for each period of each experiment are taken as observations. Early periods and late periods are evaluated as separate data sets. Computed for each period of each experiment is the difference between actual Y sold (net of rebuying or reselling by "speculators)" and the theoretical supply of Y at the observed ratio of average prices that period. For early periods (t = 1, 2, ..., T-4) this gives 92 observations and for late periods (t = T-3, T-2, and T-1) this gives 33 observations. The hypothesis that the difference of Y (actual total minus the theoretical total) is greater than or equal to zero is rejected for both early periods and late periods. So, actual volume lies to the left of the demand curve. That movement was toward the equilibrium was shown in Result 3.

The fact that average excess demand (given price ratios) shrinks, although insignificantly, from -0.467 in early periods to -0.167 in the late periods provides further support for the convergence part of the result. The conclusion is that this market is converging to the equilibrium from the left of the theoretical equilibrium values. □

The analysis of the output market can be treated in an analogous fashion to the input market. Again the question is about the nature of disequilibrium. Figure 5 contains the static competitive equilibrium demand and supplies expressed as a function of the price ratios (given in (10) and (12)). As was the case in the analysis of the input market, the data for average prices and volumes for the early periods of each experiment are in the upper graph and those for the late periods are in the lower graph. As was the case in the input market, the data lend themselves to an interpretation that the output market is in disequilibrium. An excess demand seems to exist in the sense that price is above marginal cost and producers are not moving to completely respond with the competitive quantity to be applied at that price. The notion is captured by the next result and by Result 7.

Result 5. The output market is in disequilibrium. The market volume is less than both the theoretical quantity demanded and the theoretical quantity supplied. The movement is in the direction of the partial equilibrium but the statistical significance level for the movement is mixed.

Support. Observe the data as presented in Figures 5a and 5b, and notice that the per agent quantities are always to the left of both the demand curve and the supply curve given the price ratio that existed on average in each of the markets. The statistical model is the same as was applied in Result 4. Early periods ($t = 1, 2, ...,$ T-4) and late periods ($t =$ T-3, T-2, and T-1) are considered to be different data sets. For each period of each experiment the theoretical demand is computed at the ratio of average prices of X to average prices of Y for the period. The theoretical market supply is computed in a similar fashion. The hypothesis that actual volumes are greater than or equal to theoretical is rejected in all data sets. Thus the activity lies to the left of both the demand curve and the supply curve.

That movement of output volume toward the equilibrium has been shown by Result 3. The movement of X_{jp} toward the equilibrium in Table 8. is significant, while the movement of X_{ic} is not. The fact that excess demand (given price ratios) shrinks significantly (at the $p < 0.025$ level) from -1.761 to -0.515 in the late periods provides further support for the convergence part of the result. □

The next two results focus on the behavior of individual agent consumers and producers. The analysis above suggests that excess demand exists in both the input market and the output market. Walras law tells us to be careful about any such conclusion. The analysis now focuses on the decisions of the individuals and locates the behavioral key in the actions of the supply side of both markets.

Consumers are consuming too much Y and not releasing it to the market similar to the over consumption of leisure that one might expect from a model of voluntary unemployment. Similarly producers fail to supply enough X. In a sense the producers also over consume Y because they consume the Y rather than using it as a factor of production. Of course one can speculate about risk aversion or other potential reasons for the phenomena but given the data in these experiments there seems to be no way to pin down the causes. Additional experiments focused directly on this issue will probably be necessary. For now, the next two results simply record the observation.

Result 6. Given the price ratios, too much Y is consumed by consumers.

Support. According to the static competitive equilibrium model, the equilibrium consumption of each individual is 6 units of Y. In early periods, the average price ratio across all markets, is 2.13, and the consumption of Y by the average consumer who optimally responded to this ratio would be $Y = 5.80$ units per period which is significantly less than the actual average consumption of $Y = 6.93$ per period. Similarly in late periods, the average price ratio across all markets, is 1.99, and the consumption of Y by the average consumer who optimally responded to this ratio would be $Y = 6.02$ per period which is significantly less than the actual average consumption of $Y = 6.68$ per period. The frequency distribution of deviations of the individual actual consumption of Y from the theoretical optimum is shown in Figure 6a for early periods and in Figure 6b for late periods. Further statistic tests show that the deviations are significantly positive for both early and late periods, and the overconsumption decreases significantly (at the $p < 0.0025$ level) over time. □

Result 7. Given the price ratios, producers under produced X and over consumed Y.

Support. If the price is above the marginal cost of producers, then an under supply of X exists. If the producers are consuming Y then they have failed to use some of the consumed units in production which, theoretically, could have been used to produce more X, which when sold would generate enough money to buy and consume even more Y. In early periods, the observed average price ratio is 2.13 at which the producer should have used 1.94 units of Y on average per period. In fact the individual producer only used 1.46 units on average per period. Similarly in late periods, the observed average price ratio is 1.99, and the producer should have used 2.01 units of Y on average per period. In fact the individual producer only used 1.58 units on average per period. In both cases, the actual units of Y is significantly lower than the optimum. It follows that price was above marginal cost and since all producers consumed some Y each period the result is established. The frequency distribution of deviations of the individual actual production of X from the theoretical optimum is shown in Figure 7a for early periods and in Figure 7b for late periods. Further statistic tests show that the deviations are significantly negative for both early and late periods, and the underproduction decreases, although insignificantly, over time. □

The last two results could have been anticipated from Figures 4 and 5. However, the figures and the period averages obscure the fact that the over consumption was widespread among the agents. The low variances implied by the t-statistics indicate that the phenomenon was widespread and therefore worthy of mention as results. However, it should be emphasized that the system is still moving towards the equilibrium. The over consumption is necessarily falling over time toward the static general competitive equilibrium quantities. The two previous results simply say something about the nature of the disequilibrium and not about the general tendency toward equilibration that was observed.

5.3 Macroeconomics Variables

The fact that the whole economy is up and working invites an investigation of variables that are found in the macroeconomics literature. The fact that no real investment was possible, and there was no way for productivity to be effected by saving and investment, precludes the analysis of phenomena that is thought to be of major importance to the evolution of economies over time. Nevertheless, measurements can be made and interesting questions can be posed. The first questions focus on the price levels and the money supply.

Result 8. With a constant money supply, price levels increase during the duration of the economy, and approach asymptotes. The inflation rates asymptote to zeroes.

Support. The average prices of X and Y for each period of each experiment are in Table 10. Of the 40 period to period average price changes that can be calculated for each of X and Y, 39 are price increases for X and 30 are price increases for Y. Thus the prices are moving upward for the duration. The data from series 1, which are not included, lead to the same conclusion. The relevant dependent variables and parameter estimates for other variables are in Table 11. In order to show that price levels asymptote, we calculate the periodical changes of the price levels and demonstrate they converge to zeroes. As can be seen in Table 11, the periodical change of the price level of X, dP_X, converges to zero in both the weak and the strong senses, and the periodical change of the price level of Y, dP_Y, weakly converges to zero for all nine times. Thus, price levels converge to asymptotes. Lastly, in order to show the inflation rates asymptote to zeroes, a standard consumer price index (CPI) is constructed as follows:

$$CPI = (8P_X + 2P_Y)N, \tag{17}$$

where 8 and 2 are the amount of X consumed by each consumer and the amount of Y consumed by each producer respectively in equilibrium. N is the number of consumers and the number of producers. In other words, choose those consumption levels of X and Y in equilibrium as consumption bases for the consumption bundles in the economy.

Now the inflation rate is defined as the percentage change of consumer price index from period to period, i.e.,

$$\pi^t = \frac{CPI^t - CPI^{t-1}}{CPI^{t-1}}. \tag{18}$$

As can be seen in Table 11, the inflation rate approaches zero in both the weak sense and the strong sense.

When the statistical model is estimated separately for series 1 experiments and series 2 experiments, all of the conclusions listed above are supported. Since series 2 had different money supplies across experiments we can conclude that the level of the money supply did not change the above results. □

A natural measure of Gross National Product seems to be possible. Measures that follow from this measure provide a means of supplementing the static general equilibrium model. Following the standard definition, Gross National Product (GNP) is the market value of all final goods and services produced in the economy during a time period (usually one year). The year period in these economies is taken to be one period of the experiment.

GNP can also be defined as consumption plus investment plus government expenditures. Government expenditures are zeroes in these economies. Consumption is consumption of X by consumers and consumption of Y by producers. The consumption of Y by consumers does not appear because it is not sold in the market (like leisure). Those Y's used in production do not appear in GNP because they are "intermediate" goods as opposed to "final" goods. Capital investment is not possible in these economies so the only investment that can occur is in inventories. Therefore investment is defined as the period to period change in inventories of X and Y by consumers and producers, $\Delta\mathrm{INV}_X$, $\Delta\mathrm{INV}_Y$.

In summary:

GNP = X's consumed by consumers + Y's consumed by producers + Inventory changes by producers and consumers. i.e.,

$$GNP = C + I, \tag{19}$$

$$\text{where } C = P_X \sum_{i=1}^{N} X_{ic} + P_Y \sum_{j=1}^{N} Y_{jc}, \tag{20}$$

$$I = P_X \sum \Delta INV_X + P_Y \sum \Delta INV_Y. \tag{21}$$

The full employment GNP is defined to be the sum of static competitive equilibrium quantities of X and Y weighted by the current prices (investment should be zero), i.e.,

$$GNP^* = P_X \sum_{i=1}^{N} X^*_{ic} + P_Y \sum_{j=1}^{N} Y^*_{jc}, \tag{22}$$

that is, $GNP^* = N(8P_X + 2P_Y)$.

Define income velocity as the ratio of GNP to the total money supply M^s in a period, i.e., velocity measures how many times a unit of money circulates in the economy in a period.

$$V = \frac{GNP}{M^s}. \tag{23}$$

The income velocity of money was computed for each period of each experiment. The numbers are included in Table 12. Looking at the table one can see a tendency for the velocity to increase with time (except for series 3). This should come as no surprise in light of the previous result that prices were increasing with time and the fact from general equilibrium analysis that the system is close to the static competitive equilibrium. The table also indicates that the velocity of money in series two, in which subjects were experienced (they participated in series one), is higher than the velocity in the economies studied in series one. This suggests that experience might have an influence on velocity. The data from series two, in which the money supply differed dramatically among experiments, suggest that the constant level of the money supply had no effect on the velocity. However, when the money supply varied as it did in series three starting with period four, velocity first fell and then experienced an increase. These patterns are made precise in the next result.

Result 9. With a constant money supply, income velocity of money increases with time and experience, approaches an asymptote, that is independent of the level of a fixed money supply.

Support. First addressed is the propensity of velocity to increase with time. This property is closely related to price increases so the arguments are very similar to the one that were used in Result 8. The velocity numbers are in Table 12. Considering only series 2 periods, of the 49 possible changes, 37 are velocity increases. Thus velocities increase with time. An analysis of series 1 supports the same conclusion. In order to test whether the income velocity asymptotes, we calculate the periodical change of the income velocity of money, dV, and show it converges to zero. As can be seen in Table 11, the periodical change of velocity, dV, converges to zero in both the strong and the weak senses.[11] Thus, the velocity asymptotes.

[11]The econometric model used to support this result was also estimated separately for each series. The results confirm the conclusion listed below. They are not included because of space constraints.

The effect of experience can be determined by a comparison with series one and series two in Table 12. In the latter experiments the agents had experience as participants in series one. A comparison of the velocity numbers of the two series of experiments in Table 11 shows that in only two cases out of forty eight comparisons is the velocity of an experiment in series one greater than the velocity of the same period in an experiment in series two. That is, in a period by period comparison the velocities in series two virtually dominate the velocities in series one. Since the primary difference in the experiments was experience (in some cases the money supply was the same) the result is established by a simple Wilcoxon signed-rank test. The hypothesis that the velocity of series two is less than or equal to the velocity of series one can be rejected at the 0.01 level.

The possible effect of different levels of the money supply on velocity is captured by series two in which the money supply differed among all experiments. To establish the result it is necessary to show that there is not a monotonic relationship between the money supply and velocity. First, a comparison of the velocities between experiments 080290 (money supply equals 2000 per person) and experiment 080190 (money supply equals 250 per person) demonstrates that velocity does not decrease with an increase in the money supply (Wilcoxon signed-rank test significance at 0.001). Then a comparison between experiments 072790 (money supply equals 1000 per person) and 080290 demonstrates that velocity does not increase with an increase in the money supply (Wilcoxon signed-rank test significance at 0.001). Thus, the nominal level of a constant money supply has no uniform effect on velocity. □

The fact that the nominal money supply has no particular effect of velocity suggests that velocity might operate as a constant, at least to the extent that it will reflect the possible inflationary tendencies of increases in the money supply. The next result captures that aspect of money. Increases in the money supply will cause inflation. Figure 8, which graphs the time series of the experiments in series two, provides a visual demonstration of the positive effects of money on nominal variables. However, as stated in the result, these experiments exhibit no relationship between the real variables and the level of the money supply.

Result 10. The constant level of the money supply has a positive effect on nominal variables but has no effect on real variables.

Support. The data from series two form the basis for this result. The price time series for X and for Y are contained in Table 10. The test asks if the prices in a period by period comparison are monotonically related to the money supply. As can be seen by a visual inspection of the table the prices are on the order of proportional to the money supply. The positively monotone relationships between price levels and the money supply is supported by a Wilcoxon signed-rank test at the 0.001 level.

System efficiency (defined in (14)) is used as a measure to ascertain the possible effects of the money supply on real variables. These efficiency numbers are contained in Table 6. The Wilcoxon test for a relationship between efficiency and the constant money supply shows no monotone relationships. □

The previous results focused on economies in which the money supply was constant. Of course much of the interest in money stems from the case in which the change in the money supply is not anticipated. Series three provided an opportunity to gather data on this case. The money supply started increasing at an exponential rate of 18.9% from a base of money equal to 250 per person. The increase continued for eight periods after which the growth stopped. Neither the growth nor the termination of growth were announced and the only hint of a change that subjects might have had, was an increase in their cash balances at the beginning of a period.

A glance at the velocity numbers in Table 12 for series three demonstrates the complexity of the phenomena. As the economy experienced monetary expansion at an exponential rate, the velocity falls at first and then begins to increase. Naturally this change in velocity is going to have repercussions on prices. The drama of these effects are contained in Figure 9 which shows rapid inflation followed by asymptotes or deflation. The effects on real GNP are ambiguous as can be ascertained from the study of Table 13, which will be explained in the paragraphs that follow. The lag structure is obviously complex and solid conclusions are going to be difficult with such a short time series. Any detailed analysis of these data is far beyond the scope of this paper and the competence of the authors.

Real GNP is defined as follows

$$RGNP = (\sum_{i=1}^{N} X_{ic} + \sum \Delta INV_X) + 2 * (\sum_{j=1}^{N} Y_{jc} + \sum \Delta INV_Y). \tag{24}$$

That is the real GNP is the sum of real consumption and net inventory changes taken P_X as a numeraire in equilibrium (i.e., $P_Y = 2P_X = 2$).

In addition, define the potential real GNP as the real GNP in general competitive equilibrium, i.e.,

$$RGNP^* = N(8 + 2 * 2) = 12N. \tag{25}$$

Table 13 contains the real GNP measurements for each period of each experiment. The full employment levels are listed at the top of the table. As the table illustrates, the real GNPs are constant for the most part, after a few periods of adjustment. One should notice that the real GNP measurements do not move in one to one correspondence with the efficiency measurements in Table 6. The differences are due to the facts that the efficiency numbers contain "leisure consumed" while the real GNP does not and real GNP contains inventory changes, while efficiency does not. In addition, the efficiency measure is nonlinear in the sense that the value of marginal units fall while all units weigh the same in the real GNP measurements. No doubt the relative movements of these magnitudes reflect the nature of disequilibria in the underlying economy and the possible responses to monetary variables but any attempt to model these complex relationships is far beyond the scope of the paper.

The next result involves another classical type of question. Does a negative relationship exist between changes in unemployment and the percentage change in real GNP? The relationship is regularly observed in field observations as Okun's Law (see Okun (1970)) so it is a natural question to pose of the experimental data. After having studied the static general equilibrium results the discovery of the operation of the law should perhaps be no surprise. A fall in unemployment translates to an increase in system efficiency and that becomes an increase in income and thus real GNP. Thus, the empirical law can be understood as a natural consequence of movements in the direction of the static general competitive equilibrium.

As regard to unemployment, we use two measurements: system unemployment and involuntary unemployment. Specifically, the system unemployment is defined as the percentage difference between the aggregate labor supply in equilibrium and the real aggregate labor supply, i.e.,

$$U_1 = \frac{4N - \sum_{i=1}^{N} Y_{is}}{4N}, \tag{26}$$

where 4 is the amount of labor supplied by each consumer in equilibrium (see Figure 2), and Y_{is} is the real labor supplied by consumer i.

The involuntary unemployment is defined as the percentage difference between the aggregate theoretical willingness to supply labor at the real price ratio $\frac{P_Y}{P_X}$ and the real aggregate labor supply, i.e.,

$$U_2 = \frac{NY_s(\frac{P_Y}{P_X}) - \sum_{i=1}^{N} Y_{is}}{NY_s(\frac{P_Y}{P_X})}, \tag{27}$$

where $Y_s(\frac{P_Y}{P_X})$ is the theoretical willingness to supply labor by each consumer at price ratio $\frac{P_Y}{P_X}$ (See Labor Supply Curve in Figure 4).

Result 11. Okun's law is observed in the data.

Support. The equation of the Okun's Law is:

$$U^t - U^{t-1} = A + B\frac{RGNP^t - RGNP^{t-1}}{RGNP^{t-1}}.$$

The equation was estimated for all experiments.[12] The results of the regressions are in Table 14. All coefficients are negative and ten of the eleven are significant. □

In passing over the data a version of the Phillips Curve (see Phillips (1957)) was also examined. Again, this type of question involves issues that are far beyond the central focus of this paper but are included for the general interest of the readers. The idea is to look for a positive relationship between inflation and the real GNP gap. i.e.,

$$\pi^t = \frac{CPI^t - CPI^{t-1}}{CPI^{t-1}} = \alpha_1 + \beta \frac{RGNP^{t-1} - RGNP^*}{RGNP^*},$$

where inflation (π), real GNP (RGNP) and the potential real GNP in equilibrium ($RGNP^*$) are defined respectively in (18), (24) and (25).

The results of the regressions are in Table 15 and are generally negative. The Phillips curve was not observed. The next result summarizes the finding.

Result 12. The data give no support for the existence of a Phillips curve.

Support. Regressions were run for all eleven experiments. The coefficients and significance level are in Table 15. All eleven coefficients should be negative but only seven are negative and only three of these were significant. Four of the experiments gave positive coefficients and two of these were significant. There seems to be no support for the Phillips Curve, at least with these models as specified. The analysis was pursued to the expectations augmented Phillips curve (see Phelps (1967) and Friedman (1968)). □

Collectively the results give the impression that secular inflation exists as a natural part of an equilibration process that approaches an asymptote but may always be present. It is clear that some physical bounds exist for inflation in a cash in advance economy. If the price level is sufficiently high the entire money supply would be required for each transaction. At such high price levels, a very high level of coordination would be required as the money supply would need to exist in the hands of each person wishing to make a transaction. For an experiment with ten people and 2000 francs money supply each, such as 080290, the price of Y would be 20,000 francs per unit as opposed to the 1700 or so francs that is observed. Thus there is a logic with which can be joined with the facts of the economy to produce a real upper bound on what might take place by way of price levels. Inflation cannot go unbounded with a constant money supply. Since an asymptote must exist, what might govern the level?

A host of incidental observations suggest that uncertainty in the economy and the capacity of individuals to manage their money govern the rate of inflation. As the economy approaches a static general competitive equilibrium as these economies do, the

[12]Since unemployments U_1 (defined in (26)) and U_2 (defined in (27)) are highly correlated, U_1 is used here.

level of predictability increases. Trading patterns develop as the coordination forced by the equilibration process begin to take form. As a result cash is less valued as a tool that allows the agent to take advantage of unanticipated events. In addition as an individual gains experience functioning in the economy he/she becomes a better money manager.

The collection of impressions about the nature of the use of money and the equilibration process are contained in the following conjecture and its support.

Conjecture 1. Secular inflation occurs as a natural aspect of the convergence of the economy to the static general competitive equilibrium.

Support. Time in the economy generates a weak convergence to the static competitive equilibrium as was shown in Result 3. This convergence process is accompanied by a decreasing rate of inflation, Result 8, and velocity that increases but at a decreasing rate, Result 9. The increase in velocity with experienced people suggests that it is responsive to their abilities to deal with their cash in a better manner. □

6 CONCLUDING REMARKS

This project started with a question about the circular flow of income and resources model that is used by economic textbooks to describe the operation of an entire economy. The time dependencies implied by that model are very complex. Output price is to be influenced by market supply of output which is determined by the cost of output. Output cost depends upon the prices of inputs which depend upon the demand and supply of the input. Of course, input demand depends upon output price and since input price is a source of income for output demanders, input price has an influence on output demand and thus output price. This logic causes no problems at all to those who understand the nature of static general equilibrium models. The question that motivated this study was not about the logic. The question was about whether or not the logic had any capacity at all to predict what actually happens in a simple economy populated with real people making real but highly interdependent decisions.

The first question posed by the research was whether or not it is possible to even create a fully functioning economy in the laboratory with many of the interdependencies that are implied by the circular flow model. The procedures section of the paper and the appendix provide the new technology needed to accomplish this task.

Once the ability to create an actually functioning economy had been accomplished, more detailed research questions began to take form.

Do the economies suffer from the lack of order that the critics of market economies often claim will be pervasive? The economies clearly had none of the features of randomness, cycles and lack of coordination that some of history's most (politically) powerful theories maintain. The first result demonstrates that theories about the generic lack of order of unplanned, decentralized systems are clearly wrong. The second and third results provide the sense in which the data are consistent with the static theory of general competitive equilibrium. Even though many of the assumptions of the model are violated and the model is not perfect, the data from all sectors of the economy are converging to the magnitudes predicted by the static general competitive equilibrium model. In other words the message from these economies is that the static theory of general competitive equilibrium is empirically useful. It captures much of what is observed. The conclusion of this paper is that model must be taken seriously as a set of principles that describe how an economy operates.

The economies experienced some sort of convergence or equilibration process. Equilibration has been observed many times in less interdependent experimental market environments so the process of equilibration in the general equilibrium setting is of great interest. Results 4 and 5 indicate that the process of equilibration is not one in which partial equilibrium is first established in some sub market like the input market, after which the other markets become equilibrated. Disequilibrium is in all markets simultaneously. The markets move toward their respective partial equilibrium. The path taken by the equilibration process is best described as from the "left". Clearly additional experiments under a variety of different environments are required before any consistent story about the nature of equilibration will emerge. The results simply reflect patterns that others might want to look for in their data. It is one place for the analysis of others to start.

The equilibration process itself holds an interesting paradox. Price ratios tend to approximate the static general equilibrium magnitudes rather closely while quantities are still in a period of adjustment. By contrast a Marshallian process of quantity adjustment is frequently observed in single market experiments. Quantities adjust and prices follow. This property may be a consequence of the particular parameters of these experiments or it may be suggesting something deeper about the principles that govern the static general system equilibration. For the moment we cannot say.

The circular flow model is closely associated with macroeconomics models and once the economies were actually functioning an opportunity presented itself to test some of the classical ideas that have existed in the economics literature for over a hundred years. Even the creation of an economy with fiat money provided the opportunity to ask about the absolute level of prices as opposed to only the relative prices that are the subject of general equilibrium theory. The question posed was whether or not the money supply would effect the economy.

Nominal effects of the money supply are clearly evident. The level of the money supply has a direct effect on the price levels and under some conditions the effects are proportional to the quantity of money. The velocity of money appears to gradually increase over time and approach an asymptote. Velocity is effected by both the time over which the economy has operated and the experience of agents in the economy in general. The inflationary effect of the time over which the economy has operated with stationary parameters (velocity increases with time) is probably related to the equilibration process described by the static general equilibrium model. As equilibrium is approached the system becomes more predictable and the desire of individuals to hold cash balances diminishes. The effect of the general experience of agents seems to reflect a different sort of phenomena that is related to the ability and speed with which individuals can execute decisions and is thus related to the ability of agents to manage money. As individuals learn how to quickly and accurately translate decisions into actions their ability to manage their money increases and thus velocity of money increases as well. The effect of money on nominal variables is most clearly seen in the series three experiments in which the money supply undergoes an uncertain increase for several periods after which the increases stop. Prices increase with a lag. Velocity falls at first and then begins to increase but the response of velocity differs between the two economies which experienced the same shock.

No effect of the money supply on real variables was detected. Practically speaking, the bond markets never opened in these economies. This is not particularly surprising since individuals tended to manage cash to avoid the need for borrowing and time preferences for consumption did not exist. There is no evidence of a Phillips curve relationship that we were able to measure. It might be possible to measure such effects in economies that are operating in a different parametric environment or in economies in which the money supply undergoes an unexpected decrease as opposed to an unexpected increase.

We do find strong evidence for Okun's Law. That is, there is a strong negative relationship between real GNP and unemployment. Of course such a relationship can be interpreted as a natural consequence of the equilibration process in a static general equilibrium sense. As the economy gets closer to the static general equilibrium the efficiency level increases which means that both real incomes (GNP) increase and unemployment levels decrease. Okun's Law can be seen as a consequence of the decentralized price system to coordinate activities in order to exhaust the potential gains from trade.

Of course it is easy to inquire about the possibility of different experiments and different nodels. What if the economy had unstable equilibria? What would happen if the equilibrium did not exist? Suppose there were many more inputs and intermediate goods. What would happen if savings could be productively employed or if productive capital formation could take place? Could the decentralized mechanism still move toward the general equilibrium? What if price controls existed or what if the production functions were of a different shape? Could the accuracy of the competitive model be improved by adding the agents to have expectations and choose in accord with principles derived from dynamic considerations? All of these questions and many more are unanswered. We have only demonstrated by producing an example that the equilibration process described by the classical models can work as advertised over the decades. Some might feel that we have only demonstrated the obvious. We would only suggest that such critics turn to the section of the paper that contains the parameters and without peeking to see the solutions in the text, see if they can compute the competitive equilibrium as fast as the market did it and while doing the computation remembering that the market did it without any agent in the economy knowing anything but his/her own parameters.

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Appendix A
GENERAL INSTRUCTIONS

This is an experiment in the economics of market decision-making. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash.

In this experiment, we are going to conduct a market in which you will be a consumer in a sequence of trading periods. Some of you will also have the capacity to produce. Attached to the instructions you will find a sheet called "Payoff Table" which will help determine the value to you of any decisions you might make. If you have the capacity to produce you will also have a sheet labeled "Production Schedule". YOU ARE NOT TO REVEAL THIS INFORMATION TO ANYONE. It is your own private information.

The currency used in this market is francs. all trading will be in terms of francs. Your final payoffs will be in terms of dollars.

THE PAYOFF TABLE: CONSUMPTION

Find the payoff table in your folder. Your dollar payoff is determined at the end of each period either by the number of units of Y that you have chosen to consume during that period, or by the number of units of X that you have chosen to consume or by both X and Y depending upon the table you happen to have been given. Your payoff table shows the dollars you will receive as a result of the decision you make. You can determine your earnings by using the payoff table at the end of each period once you have made consumption decisions for that period.

The following two completely hypothetical examples will show you how to read the table.

Example 1: Suppose that you have the payoff table given as example 1, in which your payoff depends only upon your Y consumption. Suppose further that for some period you have chosen to consume three Y's. Your dollar payoff in this case is determined as follows. Find the column corresponding to three Y's consumed. The total payoff for that number of units is 2400 (in the shaded area). If during the period you had decided to consume four Y's rather than three your payoff would have increased by 600 which is the UNIT payoff of the fourth Y. The TOTAL payoff for the four units of Y's consumed would be 3000. The total payoff is the dollar amount you receive and the unit payoff is the amount your total payoff changes if the additional unit is consumed.

The Attached Record sheet should be filled out at the end of the period. The number of X's consumed that period is recorded on column 4. The number of Y's consumed is recorded on column 5. The payoff for the period is recorded on column 6. If four Y's were consumed then your Record Sheet should show zero X's on column 4, four Y's on column 5 and a payoff of 3000 on column 6. Your inventories at the end of the period should be recorded in the inventory columns.

Example 2: Suppose, you have the payoff table for example 2, in which your payoff depends upon both your Y consumption and X consumption. Suppose further that you have decided to consume two X's and three Y's. Your dollar payoff in this case is determined as follows. Find the row corresponding to two X's and the column corresponding to three Y's and read the entry for the total payoff; the amount is 1400 (in the shaded area). This would be your dollar payoff for that period. If you had decided to consumed three X's and three Y's, your total payoff would be 1700 instead of 1400. The unit payoffs indicate the effect on your payoff of a one unit change in consumption. For example the third X added its unit payoff of 300 to your payoff.

The Record Sheet would be filled out as follows. Suppose three X's and three Y's were consumed. Column 4 would show three X's. Column 5 would show three Y's. Column 6 would show a payoff of 1700 for the period. Your inventories at the end of the period should be recorded in the inventory columns.

ENDOWMENTS

At the very beginning of the experiment you will be given a one time endowment of ___ francs cash on hand and ___ X's and ___ Y's. You can see them on your screen. Each period after the first you will be given an additional endowment of ___ francs cash on hand and ___ X's and ___ Y's which will be added to whatever amount you decided to carry over from the previous period. If you are not given any additional endowment for a period then you must plan to carry over whatever you might need.

HOW THE SYSTEM WORKS

In order to buy anything you must have enough cash in francs. Unless you are endowed with additional francs each period you can only acquire francs by selling something. Some people want to consume both X's and Y's but have no X's. They must sell Y's in order to get the francs to buy X's. How many Y's an individual would want to sell or how many Y's the individual would want to retain for consumption depends upon the individual.

Some people want to consume only Y's which must be bought with francs. These people have the ability to use Y's to produce X's. Thus, one way of acquiring Y's is to use some Y's to produce X's. These X's can then be sold for francs to get more Y's. How many of their Y's they consume and how many they use to produce X's depends upon the individuals.

TIME AND THE END OF THE EXPERIMENT

The market system is organized as follows. The market will open in a series of trading periods, each of which lasts for at most ___ minutes. The last period will be announced one period before it opens.

At the end of the last period of the experiment, all unconsumed inventories of X's and Y's will be worthless. All cash on hand will be converted into units of X's or Y's (your choice) at the average price of the last period. For example, suppose you hold 900 francs cash on hand at the end of the experiment. If the prevailing price of Y is 300 francs per unit of Y, then your cash on hand can be converted into 3 units of Y (i.e., 3 = 900 /300), which you can then add to your consumption units for the final period. Thus, there is no need for you to attempt to hold zero balance of francs at the end of the experiment.

BORROWING MONEY

You have an inventory of "bonds" which will allow you to borrow money for the length of one period. Each "bond" represents a commitment to repay 100 francs. That is, the money you receive from the SALE of a bond is BORROWED for one period. At the end of the period you must repay 100 francs to the holder for each bond you sold. Suppose you sold a bond for 80 francs. At the end of the period you must pay the holder a total of 100 francs. That is, your repayment amounts to the 80 francs borrowed plus 20 francs "interest".

When you BUY a bond you are LOANING money. You will be repaid 100 francs by the person who sold it at the end of a period for each bond you buy. The 100 francs must cover BOTH what you paid for the bond (the amount you loaned) and the interest you want.

Two bond markets will be open. The "END-PERIOD BOND" market repays at the end of the period in which it was sold. The "MID-PERIOD BOND" market repays at the middle of the period. It allows a loan to be made at the late part of one period and repaid at the middle of the next period.

NOTICE: You must have adequate cash to pay all bonds when bonds you sold are due. If you sell bonds, make sure that you have at least 100 francs on hand for each bond sold when the bonds are due. Failure to cover loans will result in an $ ___ fine.

THE TECHNOLOGY OF CONSUMPTION

All consumption decisions must be made BEFORE the end of the period. You consume X's by transforming X inventory from market 1 to market 5 BEFORE the end of the period. Units of X held as inventory in market 5 at the close of a period are consumed and disappear when the period ends. You consume Y's by transforming Y inventory from market 2 to market 6 BEFORE the end of a period. Units of Y held as inventory in market 6 at the end of a period are consumed and disappear when the period ends. The computer will automatically record them as having been consumed. The F10 key can be used to check the record. BE SURE to transform the units you want to consume from markets 1 and 2 to markets 5 and 6 BEFORE the period ends. Otherwise the units will remain unconsumed as inventory in markets 1 and 2 and you will receive no payoff for that period.

SOME NOTES

No talking;

No "flashing"(i.e., rapid cancellation);

No advantage to grabbing typos;

Be sure to consume before the period ends;

Beware of "sliding"(i.e., low bids (high asks) when sellers (buyers) are rapidly accepting);

Beware of "switching" (e.g.., bids of 1 for 5 units when people have been bidding 5 for 1 unit).

Note: This payoff table is for instruction only.

PAYOFF TABLE (EXAMPLE 1)

Identification No:______

No of y Consumed	0	1		2		3		4		5		6		7	
	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total
	0	900	900	800	1700	700	2400	600	3000	500	3500	300	3800	200	4000

8		9		10		11		12		13		14		15		...	
unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	...	...
100	4100	100	4200	100	4300	100	4400	100	4500	100	4600	100	4700	100	4800		

Record Sheet

ID No: ____

Period	Cash on hand (1)	Market 1 Inventory (2)	Market 2 Inventory (3)	X Consumed (4)	Y Consumed (5)	PAYOFF (6)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						

Francs on Hand:__________ Sum of Payoffs __________

Name:__________ Social Security Number:__________

Address:____________________

PAYOFF TABLE (EXAMPLE 2)

Identification No:________

No of X Consumed \ No of Y Consumed		0	1		2		3		4		5		6		7		
		total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	
0	total	-500	200	-300	100	-200	150	-50	350	300	600	900	50	950	0	950	
1	unit	300		150		600		1150		1000		500		500		500	
	total	-200	50	-150	550	400	700	1100	200	1300	100	1400	50	1450	0	1450	
2	unit	20		650		400		300		200		150		150		150	
	total	-180	680	500	300	800	600	1400	100	1500	50	1550	50	1600	0	1600	
3	unit	580		500		550		300		300		330		330		330	
	total	400	600	1000	350	1350	350	1700	100	1800	80	1880	50	1930	0	1930	
4	unit	280		300		150		200		200		190		190		190	
	total	680	620	1300	200	1500	400	1900	100	2000	70	2070	50	2120	0	2120	
5	unit	60		50		100		180		200		230		230		230	
	total	740	610	1350	250	1600	480	2080	120	2200	100	2300	50	2350	0	2350	
6	unit	40		30		70		120		300		350		350		350	
	total	780	600	1380	290	1670	530	2200	300	2500	150	2650	50	2700	0	2700	
7	unit	0		0		0		0		0		0		0		0	
	total	780	600	1380	290	1670	530	2200	300	2500	150	2650	50	2700	0	2700	

CONSUMER QUESTIONS

Assume your screen looks as follows:

ID: ·

Cash on Hand 120

Market	Period	Time	ID	Bid Price	Quantity	ID	Ask Price	Quantity	Inventory
01 *X* Market	..	..	.	...	..	.	20	30	1
02 *Y* Market	..	..	.	30	20	.	...	..	8

A. You consume your inventory of *X* and your inventory of *Y*.

Your dollar payoff is $_______.

B. You sell two units of *Y* and use the revenue from the sale to buy *X's*.

Your francs from the *Y* sale _______.

Number of *X* you buy _______.

You consume the 6 remaining units of *Y* and you consume all of the *X's* you have.

Your dollar payoff is $_______.

C. You consume all 8 units of *Y* and the one unit of *X*. You spend all cash on hand to purchase and consume:

(i) 1 *X* and 3 *Y's*, or
(ii) 3 *X's* and 2 *Y's*, or
(iii) 4 *X's* and 1 *Y*, or
(iv) 6 *X's*

The option that gives you the highest dollar payoff is _________.

The dollar payoff is $_________.

PRODUCER QUESTIONS

Assume your screen looks as follows:

ID: ·

Cash on Hand $\boxed{270}$

Market	Period	Time	ID	Bid Price	Quantity	ID	Ask Price	Quantity	Inventory
01 *X* Market	··	··	·	50	20	·	·	·	0
02 *Y* Market	··	··	·	·	·	·	90	10	0

A. You do nothing.

Your dollar payoff is $_______.

B. You spend all of your cash on hand francs on *Y* and consume all you buy.

Number of *Y* you purchase _______.

Your dollar payoff is $_______.

C. You spend all of your francs on *Y*.

Number of *Y* you purchased _______.

You consume one *Y* and use the remaining units of *Y* to produce *X*.

Number of units of *X* produced _______.

You sell all of the *X*.

Number of francs received from the sale _______.

You spend all of these francs on *Y* and consume them all.

Number of (additional) *Y* consumed _______.

Number of *Y* consumed _______.

Your dollar payoff is $_______.

Table 1: Payoff Table

Identification No:________

No of X Consumed \ No of Y Consumed		0	1		2		3		4		5		6		7		8		9		10		11		...	
		total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total
0	total	-800	152	-648	136	-512	120	-392	104	-288	88	-200	72	-128	56	-72	40	-32	24	-8	8	0	16	16	16	
1	unit	36		36		36		36		36		36		36		36		40		64		72		72		
	total	-764	152	-612	136	-476	120	-356	104	-252	88	-164	72	-92	56	-36	44	8	48	56	16	72	16	88	16	
2	unit	35		35		35		35		35		35		35		35		70		70		70		70		
	total	-729	152	-577	136	-441	120	-321	104	-217	88	-129	72	-57	56	-1	79	78	48	126	16	142	16	158	16	
3	unit	35		35		35		35		35		35		35		69		70		70		70		70		
	total	-694	152	-542	136	-406	120	-286	104	-182	68	-94	72	-22	90	68	80	148	48	196	16	212	16	228	16	
4	unit	34		34		34		34		34		34		46		60		60		60		60		60		
	total	-660	152	-508	136	-372	120	-252	104	-148	88	-60	84	24	112	136	80	216	48	264	16	280	16	296	16	
5	unit	34		34		34		34		34		34		60		60		60		60		60		60		
	total	-626	152	-474	136	-338	120	-218	104	-114	88	-26	118	92	112	204	80	284	48	332	16	348	16	364	16	
6	unit	33		33		33		33		33		40		66		66		66		66		66		66		
	total	-593	152	-441	136	-305	120	-185	104	-81	95	14	144	158	112	270	80	350	48	398	16	414	16	430	16	
7	unit	33		33		33		33		33		66		66		66		66		66		66		66		
	total	-560	152	-408	136	-272	120	-152	104	-48	128	80	144	224	112	336	80	416	48	464	16	480	16	496	16	
8	unit	32		32		32		32		32		64		64		64		64		64		64		64		
	total	-528	152	-376	136	-240	120	-120	104	-16	160	144	144	288	112	400	80	480	48	528	16	544	16	560	16	
9	unit	32		32		32		32		40		64		64		64		64		64		64		64		
	total	-496	152	-344	136	-208	120	-88	120	32	176	208	144	352	112	464	80	544	48	592	16	608	16	624	16	
10	unit	31		31		31		31		62		62		62		62		62		62		62		62		
	total	-465	152	-313	136	-177	120	-57	151	94	176	270	144	414	112	526	80	606	48	654	16	670	16	686	16	
11	unit	31		31		31		31		62		62		62		62		62		62		62		62		
	total	-434	152	-282	136	-146	120	-26	182	156	176	332	144	476	112	588	80	668	48	716	16	732	16	748	16	
12	unit	30		30		30		34		60		60		60		60		60		60		60		60		
	total	-404	152	-252	136	-116	124	8	208	216	176	392	144	536	112	648	80	728	48	776	16	792	16	808	16	
13	unit	30		30		30		60		60		60		60		60		60		60		60		60		
	total	-374	152	-222	136	-86	154	68	208	276	176	452	144	596	112	708	80	788	48	836	16	852	16	868	16	
14	unit	29		29		29		58		58		58		58		58		58		58		58		58		
	total	-345	152	-193	136	-57	183	126	208	334	176	510	144	654	112	766	80	846	48	894	16	910	16	926	16	
15	unit	29		29		29		58		58		58		58		58		58		58		58		58		
	total	-316	152	-164	136	-28	212	184	208	392	176	568	144	712	112	824	80	904	48	952	16	968	16	984	16	
16	unit	28		28		28		56		56		56		56		56		56		56		56		56		
	total	-288	152	-136	136	0	240	240	208	448	176	624	144	768	112	880	80	960	48	1008	16	1024	16	1040	16	

Payoff Table (Cont.)

Identification No:________

No of X Consumed \ No of Y Consumed		0	1		2		3		4		5		6		7		8		9		10		11		...	
		total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total
17	unit	28		28		56		56		56		56		56		56		56		56		56		56		
	total	-260	152	-108	164	56	240	296	208	504	176	680	144	824	112	936	80	1016	48	1064	16	1080	16	1096	16	
18	unit	27		27		54		54		54		54		54		54		54		54		54		54		
	total	-233	152	-81	191	110	240	350	208	538	176	734	144	878	112	990	80	1070	48	1118	16	1134	16	1150	16	
19	unit	27		27		54		54		54		54		54		54		54		54		54		54		
	total	-206	152	-54	218	164	240	404	208	612	176	788	144	932	112	1044	80	1124	48	1172	16	1188	16	1204	16	
20	unit	26		26		52		52		52		52		52		52		52		52		52		52		
	total	-180	152	-28	244	216	240	456	208	664	176	840	144	984	112	1096	80	1176	48	1214	16	1240	16	1256	16	
21	unit	26		26		52		52		52		52		52		52		52		52		52		52		
	total	-154	152	-2	270	268	240	508	208	716	176	892	144	1036	112	1148	80	1228	48	1276	16	1292	16	1308	16	
22	unit	25		48		50		50		50		50		50		50		50		50		50		50		
	total	-129	175	46	272	318	240	558	208	766	176	942	144	1086	112	1198	80	1278	48	1326	16	1342	16	1358	16	
23	unit	25		50		50		50		50		50		50		50		50		50		50		50		
	total	-104	200	96	272	368	240	608	208	816	176	992	144	1136	112	1248	80	1328	48	1376	16	1392	16	1408	16	
24	unit	24		48		48		48		48		48		48		48		48		48		48		48		
	total	-80	224	144	272	416	240	656	208	864	176	1040	144	1184	112	1296	80	1376	48	1424	16	1440	16	1456	16	
25	unit	24		48		48		48		48		48		48		48		48		48		48		48		
	total	-56	248	192	272	464	240	704	208	912	176	1088	144	1232	112	1344	80	1424	48	1472	16	1488	16	1504	16	
26	unit	23		46		46		46		46		46		46		46		46		46		46		46		
	total	-33	271	238	272	510	240	750	208	958	176	1134	144	1278	112	1390	80	1470	48	1518	16	1534	16	1550	16	
27	unit	23		46		46		46		46		46		46		46		46		46		46		46		
	total	-10	294	284	272	556	240	796	208	1004	176	1180	144	1324	112	1436	80	1516	48	1564	16	1580	16	1596	16	
28	unit	34		44		44		44		44		44		44		44		44		44		44		44		
	total	24	304	328	272	600	240	840	208	1048	176	1224	144	1368	112	1480	80	1560	48	1608	16	1624	16	1640	16	
29	unit	44		44		44		44		44		44		44		44		44		44		44		44		
	total	68	304	372	272	644	240	884	208	1092	176	1268	144	1412	112	1524	80	1604	48	1652	16	1668	16	1684	16	
30	unit	42		42		42		42		42		42		42		42		42		42		42		42		
	total	110	304	414	272	686	240	926	208	1134	176	1310	144	1454	112	1566	80	1646	48	1694	16	1710	16	1726	16	
...	unit	42		42		42		42		42		42		42		42		42		42		42		42		
	total																									

Table 2: Production Schedule (Each Period)

Identification No:___

Units of Y (Input)	0	1	2	3	4	5	6	7	8	9	10	11	12	...	
Unit Output (X)	0	5	3	1	0	0	0	0	0	0	0	0	0	...	...
Total Output (X)	0	5	8	9	9	9	9	9	9	9	9	9	9	...	...

Table 3: Producer's PAYOFF TABLE

Identification No:_____

No of y Consumed	0	1		2		3		4		5		6		7	
	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total
Payoff in cents	0	*160*	160	*140*	300	*120*	420	*100*	520	*100*	620	*100*	720	*100*	820

8		9		10		11		12		13		14		15		...	
unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	unit	total	...	...
100	920	*100*	1020	*100*	1120	*100*	1220	*100*	1320	*100*	1420	*100*	1520	*100*	1620		

Table 4: Experimental Design

Date of Experiment	Subject			Parameters				
	No.	Pool	Past Experience	MS per Person	Endowments		Face Value of Bonds	No. of Periods
					per period	Period 1		
Series 1								
07/19/90*	12	HS	None	1000	cons 10 Y	cons 10 Y prod 3 X	100	8
07/22/90	8	Grad	None	1000	cons 10 Y	cons 10 Y prod 3 X	100	14
07/23/90	8	HS	None	1000	cons 10 Y	cons 10 Y prod 3 X	100	10
07/24/90	10	HS	None	1000	cons 10 Y	cons 10 Y prod 3X	100	9
07/25/90	14	HS	None	1000	cons 10 Y	cons 10 Y prod 3X	100	9
07/26/90	12	HS	None	1000	cons 10 Y	cons 10 Y prod 3 X	100	9
Series 2								
07/27/90	12	HS	One	1000	cons 10 Y	cons 10 Y prod 3 X	100	11
07/30/90	10	HS	One	500	cons 10 Y	cons 10 Y prod 3 X	100	13
07/31/90*	12	HS	One	2000	cons 10 Y	cons 10 Y prod 3 X	100	9
08/01/90	10	HS	One	250	cons 10 Y	cons 10 Y prod 3 X	100	14
08/02/90	10	HS	One	2000	cons 10 Y	cons 10 Y prod 3 X	100	15
Series 3								
08/06/90A	12	HS	Two	Variable	cons 10 Y	cons 10 Y prod 3 X	100	16
08/06/90B	12	HS	Two	Variable	cons 10 Y	cons 10 Y prod 3 X	100	16

HS: High School Summer program. Grad: Graduate students of Science and Engineering from People's Republic of China at Caltech. MS: Money supply in francs. Cons: consumers. Prod:producers.

*: Data are not used. In experiment 071990 the procedures were difficult due to its nature as a pilot. In experiment 073190 a machine breakdown occured.

Table 5: Static General Competitive Equilibrium Model Predictions

Number of Agents*	Per Capita Consumer			Per Capita Producer				Aggregate						Efficiency (%)		
											$P_x = 1$			System		
	X Consumption	Y Consumption	Per Period Dollar Income	X Production	Y in Production	Y Consumption	Per Period Dollar Income	P_y / P_x	X Volume	Y^s Volume	Per Capita Real GNP Per Period	Real GNP Per Period	Per Period Total $ Income	No Trade	Competitive Eq.	Production
8	8	6	2.88	8	2	2	3.00	2	32	16	6	48	23.52	0	100	100
10	8	6	2.88	8	2	2	3.00	2	40	20	6	60	29.40	0	100	100
12	8	6	2.88	8	2	2	3.00	2	48	24	6	72	35.28	0	100	100
14	8	6	2.88	8	2	2	3.00	2	56	28	6	84	41.16	0	100	100

*: The numbers reflect an assumption that half of the agents are consumers and half are producers.

Table 6: System Efficiency (%)

	Series 1					Series 2				Series 3	
Date	0722	0723	0724	0725	0726	0727	0730	0801	0802	0806A	0806B
Ms / Period	1,000	1,000	1,000	1,000	1,000	1,000	500	250	2,000	250 to 1,000	250 to 1,000
2	85.5	140.5 *	98.2	110.0 *	99.4	91.6	87.8	85.1	94.0	93.3	65.9
3	86.3	76.9	56.3	92.7	47.2	99.6	90.8	79.9	97.6	63.7	74.1
4	70.6	92.2	84.9	86.1	59.1	89.7	88.7	96.5	94.6	98.8	86.0
5	92.0	92.7	81.5	90.5	58.7	98.2	94.7	79.0	81.9	85.0	78.6
6	86.5	90.2	96.2	86.0	76.4	88.4	73.0	88.7	83.3	93.9	88.9
7	93.1	69.4	93.6	90.2	89.5	86.6	69.6	87.7	97.7	96.9	88.5
8	96.5	88.5	89.4	90.8	92.1	105.5*	77.6	89.2	92.6	92.9	86.2
9	86.8	99.6				99.7	93.7	90.7	88.2	94.4	93.0
10	83.9					77.8	83.8	88.9	99.1	86.2	82.6
11	96.4						86.2	89.5	83.1	94.7	85.8
12	84.6						91.6	95.5	95.0	84.2	100.3*
13	74.6							87.3	81.8	89.6	72.9
14									89.5	81.5	90.2
15										87.5	83.2
Average Excluding Period 1 and Last	86.5	93.7	85.7	92.3	74.6	93.0	85.3	88.2	90.6	88.8	84.1

* System efficiencies can be exceed 100% in any one period because of inventory choice of previous periods.

Table 7: Production Efficiency (%)

	Series 1					Series 2				Series 3	
Date	0722	0723	0724	0725	0726	0727	0730	0801	0802	0806A	0806B
Period \ Ms	1,000	1,000	1,000	1,000	1,000	1,000	500	250	2,000	250 to 1,000	250 to 1,000
2	100.0	100.0	92.9	100.0	88.9	100.0	100.0	100.0	100.0	100.0	86.7
3	91.3	100.0	84.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4	91.3	100.0	94.6	96.0	90.0	100.0	100.0	100.0	100.0	100.0	93.3
5	91.3	92.3	100.0	100.0	80.0	100.0	100.0	100.0	100.0	100.0	92.0
6	91.3	100.0	100.0	95.5	94.9	100.0	100.0	100.0	100.0	100.0	94.4
7	100.0	100.0	100.0	100.0	94.9	100.0	100.0	100.0	100.0	100.0	100.0
8	100.0	100.0	100.0	100.0	94.4	100.0	92.9	100.0	100.0	100.0	93.3
9	92.3	100.0				100.0	100.0	100.0	100.0	100.0	100.0
10	100.0					100.0	100.0	100.0	100.0	100.0	94.9
11	91.3						100.0	100.0	100.0	100.0	100.0
12	100.0						100.0	100.0	100.0	100.0	100.0
13	91.3							100.0	100.0	100.0	100.0
14									100.0	100.0	100.0
15										100.0	100.0
Average Excluding Period 1 and Last	95.0	99.0	95.9	98.8	91.9	100.0	99.4	100.0	100.0	100.0	96.8

Table 8: Predicted Allocations, Actual Allocations, Price Ratio, Price Changes, and (Standard Deviations), Series 1 and 2

Variables	X_{ic}	Y_{ic}	Y_{jc}	Y_{jp}	X_{jp}	INV_X	INV_Y	$\frac{P_Y}{P_X}$	$d P_X$	$d P_Y$
Prediction	8.00	6.00	2.00	2.00	8.00	0.00	0.00	2.00	0.00	0.00
Average 1 to T-4	6.49 (1.33)	6.93 (0.61)	1.58 (0.47)	1.46 (0.28)	6.21 (1.04)	0.54 (0.55)	0.21 (0.18)	2.13 (0.47)	35.53 (39.40)	70.67 (61.30)
Average T-3 to T-1	6.65 (0.64)	6.68 (0.34)	1.76 (0.37)	1.58 (0.19)	6.64 (0.69)	0.39 (0.37)	0.23 (0.16)	1.99 (0.17)	11.48 (11.36)	19.35 (25.59)

Table 9: Convergence Patterns over Time of Microeconomic Variables, Series 1 & 2

$$y_{it} = B_{11} D_1\, 1/t + \ldots + B_{19} D_9 1/t + B_2 (t-1)/t + u_{it}$$

Microecon Variables	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_{16}	B_{17}	B_{18}	B_{19}	B_2	Predict	Signif.	D-W	R^2
P_Y/P_X	1.80	2.64	2.18	1.89	2.56	2.41	2.49	3.07	1.94	1.97	2.00	insig	1.08	0.31
	(0.19)	(0.25)	(0.11)	(0.14)	(0.60)	(0.08)	(0.45)	(0.28)	(0.12)	(0.04)				
X^*_{ic}	4.53	7.98	4.30	5.94	2.73	5.42	4.57	4.98	4.79	6.92	8.00	$p < 0.01$	1.78	0.46
	(0.47)	(0.62)	(0.29)	(0.44)	(1.36)	(1.21)	(0.82)	(0.33)	(0.61)	(0.12)				
Y_{ic}	7.22	6.49	7.64	5.88	8.15	6.58	7.24	7.98	6.89	6.69	6.00	$p < 0.01$	1.53	0.34
	(0.23)	(0.18)	(0.33)	(0.14)	(0.28)	(0.10)	(0.37)	(0.18)	(0.14)	(0.07)				
Y_{jc}	1.81	1.99	1.15	2.55	1.21	1.55	1.11	0.69	1.77	1.71	2.00	$p < 0.01$	1.22	0.26
	(0.19)	(0.22)	(0.23)	(0.15)	(0.34)	(0.12)	(0.36)	(0.35)	(0.21)	(0.06)				
Y_{jp}	1.26	1.94	1.20	1.54	0.83	1.75	1.44	1.25	1.34	1.58	2.00	$p < 0.01$	1.37	0.28
	(0.19)	(0.06)	(0.16)	(0.10)	(0.39)	(0.18)	(0.08)	(0.11)	(0.13)	(0.03)				
INV_X	1.53	0.62	0.44	0.33	1.59	-0.06	0.60	-0.15	0.89	0.29	0.00	$p < 0.01$	0.98	0.48
	(0.21)	(0.21)	(0.11)	(0.09)	(0.43)	(0.17)	(0.08)	(0.11)	(0.21)	(0.04)				
INV_Y	-0.13	-0.25	0.09	0.13	0.27	0.29	0.44	0.29	0.12	0.25	0.00	$p < 0.01$	1.31	0.24
	(0.10)	(0.09)	(0.16)	(0.04)	(0.20)	(0.04)	(0.18)	(0.06)	(0.14)	(0.03)				

* We substract the initial 3 units of X endowment to each producer from X_{ic} in order to reflect the true trend of X consumption per consumer.

Table 10: Average Prices of X and Y by Period, Money Supply, Series 2

Periods \ Experiments (P_X, P_Y)	072790 $M^s = 1{,}000$	073090 $M^s = 500$	080190 $M^s = 250$	080290 $M^s = 2{,}000$
1	324.3, 758.6	218.3, 314.2	42.0, 147.5	319.4, 669.1
2	345.6, 801.7	219.1, 405.6	47.7, 163.6	493.4, 873.7
3	364.6, 818.5	211.8, 484.6	57.6, 158.3	591.9, 1127.5
4	381.0, 850.5	216.1, 529.2	80.9, 164.9	668.1, 1304.2
5	394.6, 841.8	217.8, 592.1	92.1, 161.2	758.5, 1430.0
6	408.0, 840.5	220.2, 602.7	94.3, 173.1	759.7, 1563.2
7	416.6, 844.9	248.9, 599.6	94.5, 175.1	768.9, 1616.8
8	424.2, 864.8	241.8, 589.3	95.4, 174.9	770.2, 1676.7
9	424.8, 878.3	253.6, 581.5	96.9, 181.8	771.3, 1690.2
10	430.3, 880.9	256.2, 580.3	97.6, 183.8	777.0, 1724.5
11	407.9, 895.2	263.2, 591.6	98.0, 186.5	784.1, 1711.3

Table 11: Convergence Patterns over Time of Macroeconomic Variables, Series 1 & 2

$$y_{it} = B_{11} D_1 1/t + \ldots + B_{19} D_9 1/t + B_2 (t-1)/t + u_{it}$$

Macroecon Variables	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_{16}	B_{17}	B_{18}	B_{19}	B_2	Baseline	Signif.	D-W	R^2
dP_X	54.8	141.1	100.7	112.3	199.0	48.1	11.5	32.6	182.2	-1.33	0.00	insig	1.89	0.67
	(30.4)	(16.8)	(21.1)	(38.0)	(13.2)	(8.6)	(16.2)	(13.0)	(28.0)	(2.91)				
dP_Y	174.7	276.5	234.2	268.0	271.1	68.3	155.0	35.9	500.0	-11.4	0.00	$p < 0.025$	1.89	0.75
	(52.5)	(64.9)	(37.3)	(40.5)	(76.6)	(22.6)	(22.9)	(23.8)	(26.0)	(5.6)				
π	0.74	1.09	1.19	0.70	0.78	0.09	0.11	0.21	0.45	-0.02	0.00	insig	2.32	0.60
	(0.16)	(0.50)	(0.28)	(0.05)	(0.38)	(0.03)	(0.03)	(0.07)	(0.02)	(0.02)				
dV	0.32	0.72	0.68	0.63	0.83	0.29	0.20	0.79	0.69	-0.02	0.00	insig	2.55	0.13
	(0.21)	(0.19)	(0.34)	(0.26)	(0.25)	(0.17)	(0.36)	(0.17)	(0.22)	(0.06)				

Table 12: Income Velocity of Money

	Series 1					Series 2				Series 3	
Date	0722	0723	0724	0725	0726	0727	0730	0801	0802	0806A	0806B
MS	1,000	1,000	1,000	1,000	1,000	1,000	500	250	2,000	250 to 1,000	250 to 1,000
Period											
1	0.38	0.14	0.41	0.33	0.16	1.75	1.44	0.90	0.57	1.98	1.73
2	0.74	0.23	0.79	0.61	0.23	1.86	2.09	0.72	1.08	2.10	1.64
3	0.81	0.63	1.20	0.71	0.51	2.05	2.31	1.16	1.51	1.79	2.23
4	0.76	0.92	1.04	0.99	0.61	2.04	2.34	1.40	1.62	1.56	1.76
5	0.93	0.83	1.57	1.10	0.92	2.11	2.07	1.66	1.63	1.44	1.46
6	1.15	1.09	1.79	1.37	1.44	2.09	2.08	1.79	1.96	1.42	1.34
7	1.45	1.07	1.75	1.61	1.60	2.23	2.74	1.87	2.03	1.18	1.49
8	1.43	1.20	1.76	1.85	1.72	2.28	1.61	1.95	2.10	1.16	1.25
9	1.36	1.30	1.80	1.80	1.47	2.29	1.96	1.93	2.19	1.42	1.42
10	1.59	1.57				2.20	2.82	1.95	2.13	2.14	1.29
11	1.26					2.35	2.82	1.96	2.17	2.51	1.21
12	1.61						2.07	1.94	2.06	2.84	1.40
13	1.29						2.73	1.93	2.07	2.91	1.56
14	1.60							2.24	2.26	3.19	1.68
15									2.12	2.93	1.89
16										2.33	1.97
Average Excluding Periods 1 and Last	1.20	0.91	1.41	1.18	1.00	2.13	2.26	1.69	1.91	2.04	1.54

Table 13: Real GNP all periods all experiments

	Series 1					Series 2				Series 3	
Date	0722	0723	0724	0725	0726	0727	0730	0801	0802	0806A	0806B
RGNP*	48	48	60	84	72	72	60	60	60	72	72
Period											
1	37	41	47	77	38	61	38	42	35	55	46
2	36	44	38	82	42	61	49	35	46	55	42
3	35	45	45	73	43	65	52	45	52	48	53
4	29	45	35	78	36	62	51	43	49	52	50
5	33	34	46	69	42	63	44	47	44	55	47
6	39	41	55	74	57	61	43	49	51	61	48
7	47	36	51	77	59	64	51	51	52	58	59
8	45	40	50	79	60	64	32	53	53	58	50
9	42	40	50	78	46	64	38	51	55	61	61
10	47	42				61	53	51	53	59	55
11	37					67	51	51	54	61	55
12	46						39	50	51	61	55
13	35						50	50	51	56	57
14	38							57	55	58	54
15									52	54	56
16										47	55
Average/RGNP* Excluding Periods 1 & Last	0.82	0.85	0.76	0.90	0.67	0.87	0.76	0.80	0.85	0.79	0.74

GNP*: Full Employment Real GNP.

Table 14: Response of Changes of Real GNP to the Changes of Unemployment Rate (Okun's Law)

$$(U_1^{t} - U_1^{t-1}) = A + B\,(RGNP^{t} - RGNP^{t-1})\,/\,RGNP^{t-1}$$

Date	0722	0723	0724	0725	0726	0727	0730	0801	0802	0806A	0806B
A	0.010	0.014	0.013	0.019	-0.024	0.006	0.005	0.002	0.010	0.004	0.011
(t-ratio)	(0.880)	(0.512)	(0.593)	(0.922)	(-0.667)	(0.778)	(0.187)	(0.441)	(1.831)	(0.157)	(0.869)
B	-0.867**	-0.991**	-0.744**	-1.620**	-0.337	-1.139**	-0.323*	-0.937**	-1.040**	-1.397**	-0.465**
(t-ratio)	(-12.733)	(-4.907)	(-6.237)	(-6.217)	(-1.632)	(-5.722)	(-2.469)	(-17.730)	(-14.427)	(-3.328)	(-4.911)
R^2	0.947	0.828	0.907	0.906	0.400	0.845	0.432	0.972	0.954	0.502	0.687
S. E.	0.038	0.073	0.054	0.051	0.080	0.022	0.087	0.015	0.018	0.101	0.043
D-W	2.590	1.265	2.426	2.608	2.456	1.939	2.170	1.667	2.620	2.857	2.416

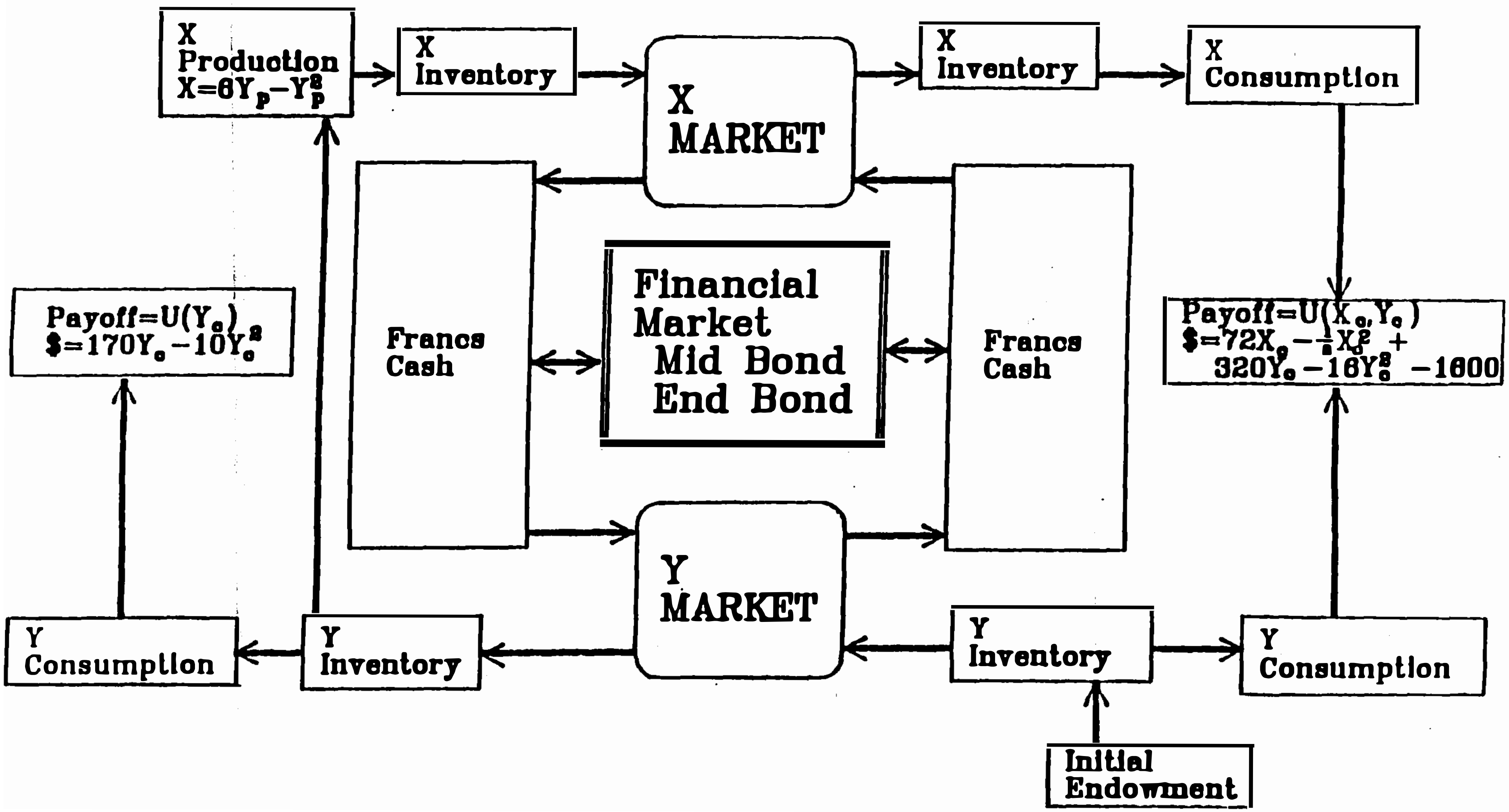
** : Significant at 0.01 level, one-tail test;
* : Significant at 0.025 level, one-tail test;
S. E. : Standard Error of the Regression;
D-W : Durbin-Watson Statistic.

Table 15: Inflation and Real GNP Gap (Phillips Curve)

Date	β (t-ratio) (Simple Phillips Curve) $\pi^{t} = \alpha 1 + \beta\,(Y^{t-1} - Y^{*})/Y^{*}$	γ (t-ratio) (Expectations-Augmented Phillips) $\pi^{t} - \pi^{t-1} = \alpha 2 + \gamma\,(Y^{t-1} - Y^{*})/Y^{*}$
072290	-0.18727* (-1.97420)	0.46631 (0.75509)
072390	3.17798 (1.29773)	-0.51983 (-0.16077)
072490	-0.48158 (-1.36918)	2.15219 (1.22550)
072590	0.61135 (0.88494)	-1.41036 (-1.33278)
072690	-1.39764 (-1.02585)	0.13805 (0.07933)
072790	-0.06285 (-0.23756)	0.31525 (1.82102)
073090	-0.01813 (-0.19704)	-0.16886 (-1.27630)
080190	-0.48909* (-1.97552)	0.16485 (0.57247)
080290	-0.70199* (-1.88670)	0.91130** (2.99454)
080690a	2.13538* (1.86808)	0.18258 (0.15097)
080690b	0.43061** (2.40516)	0.02595 (0.11707)

Y : Real GNP potential. **: Significant at 0.025 level, one-tail test.
*: Significant at 0.05 level, one tail test.

Figure 1: Circular Flow Model of the Economic System



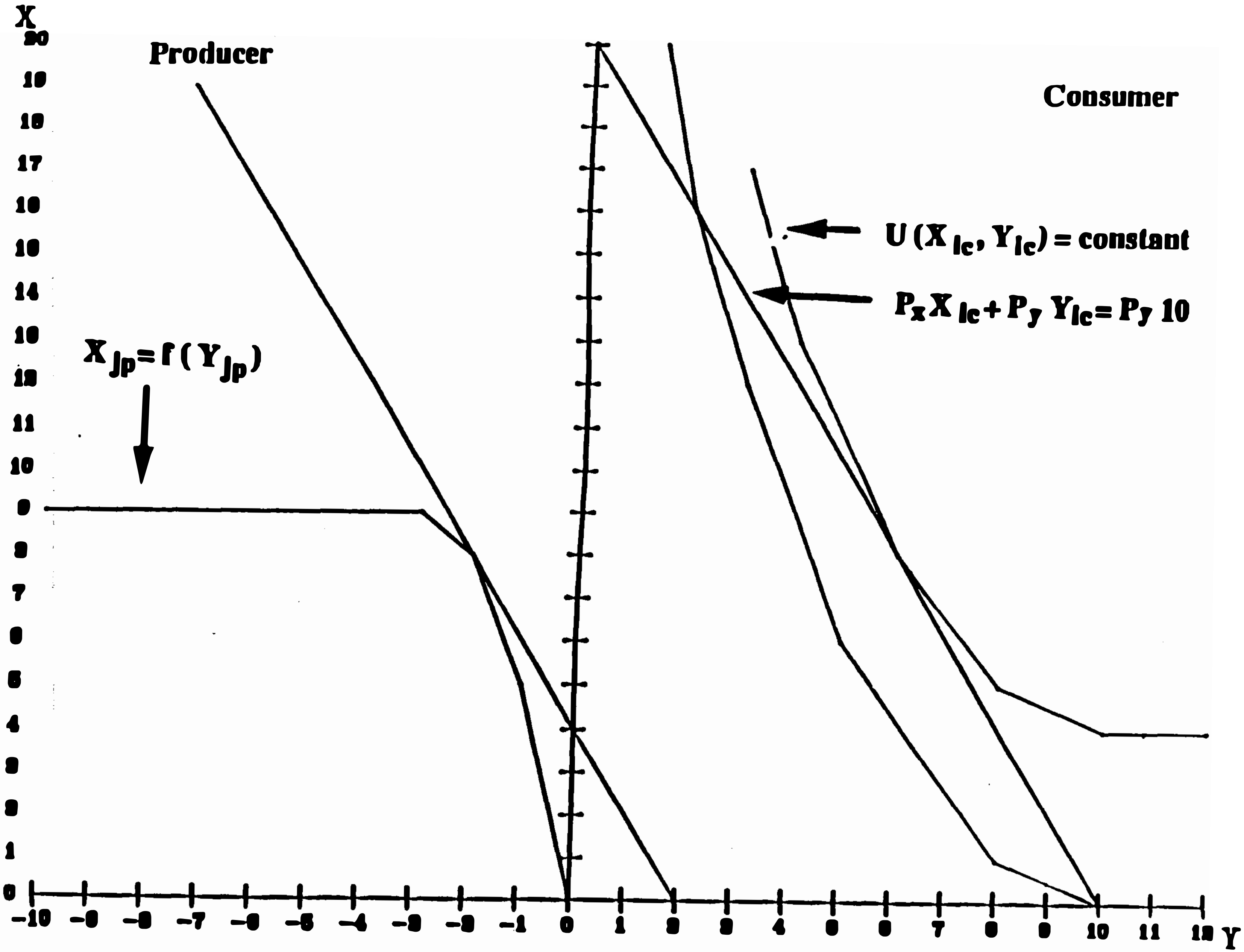
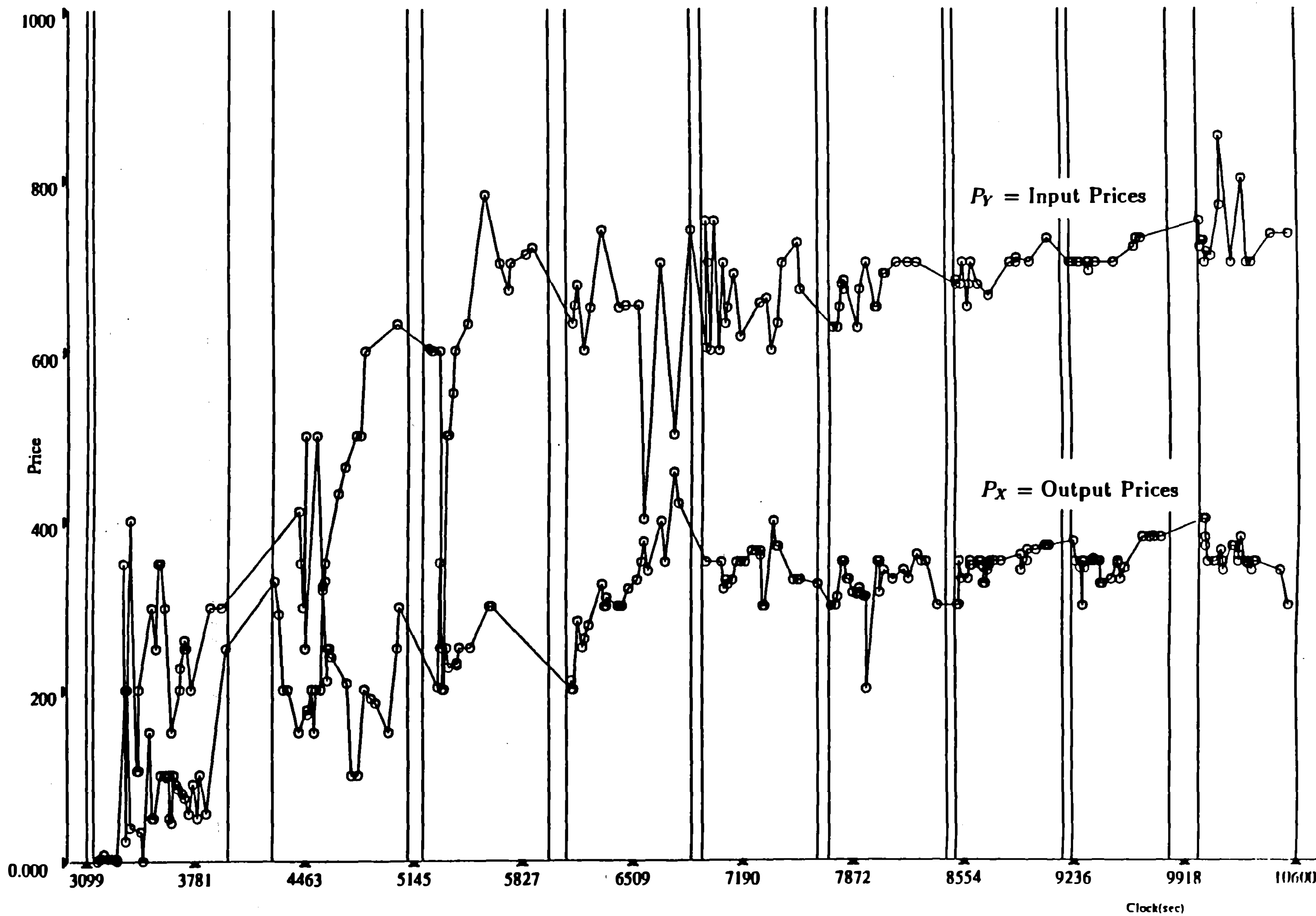


Figure 2: Static General Competitive Equilibrium

Figure 3: Contract Prices in Francs for X and Y Markets by Time (Seconds) in Experiment 072490



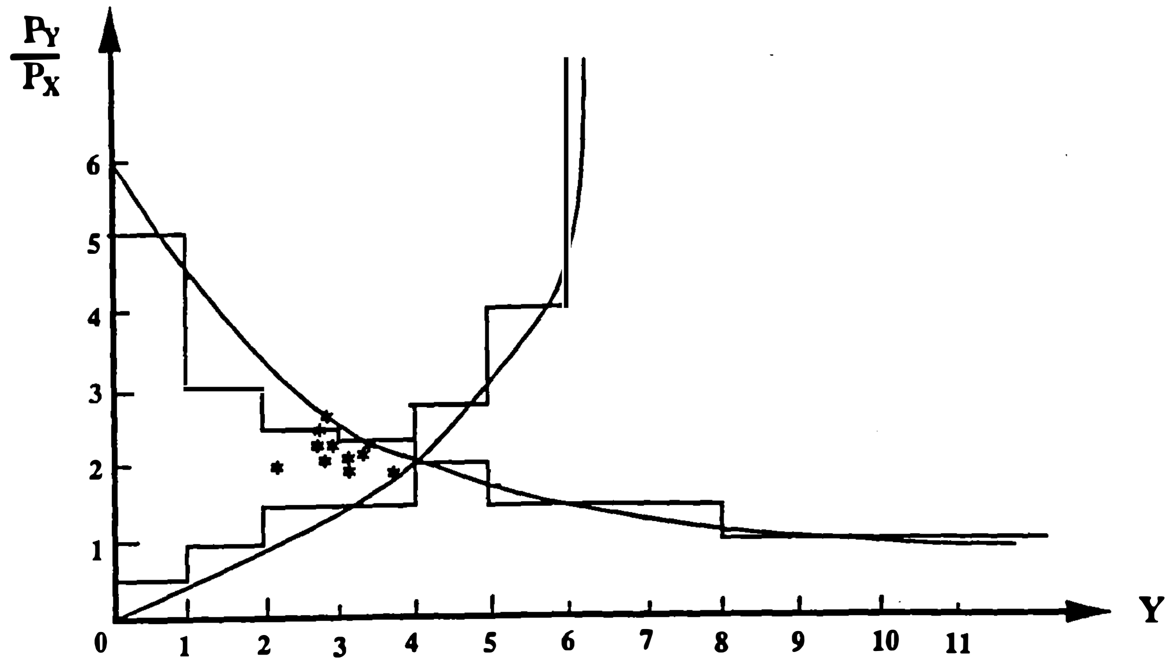


Figure 4a: Actual vs. Theoretical Y in Early Periods

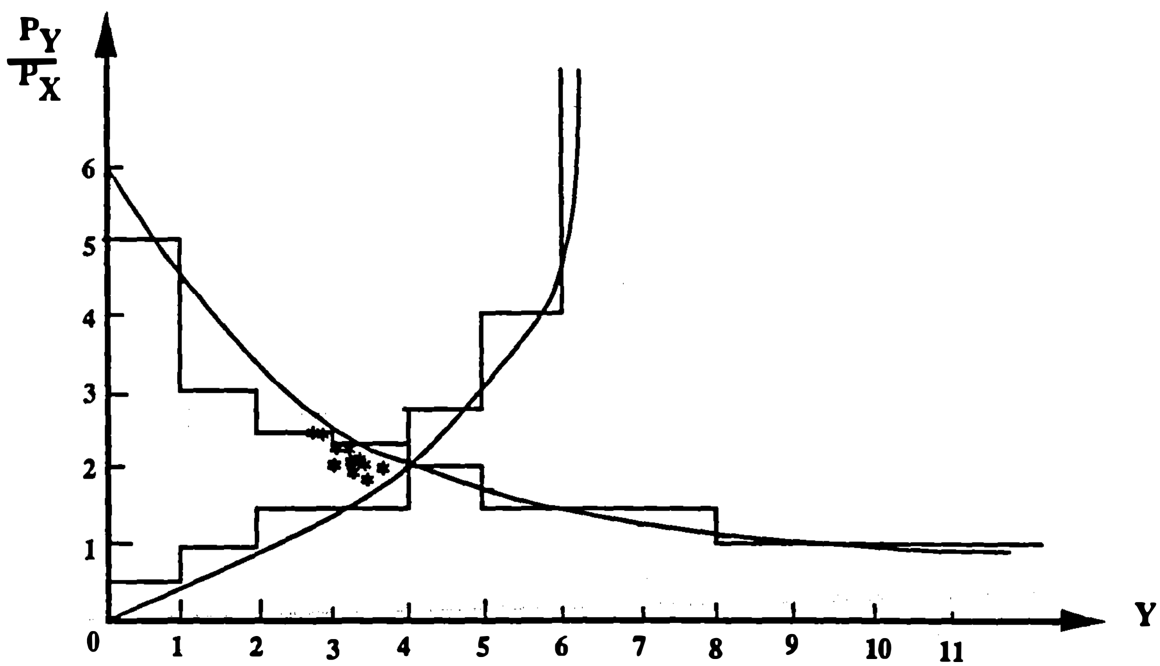


Figure 4b: Actual vs. Theoretical Y in Late Periods

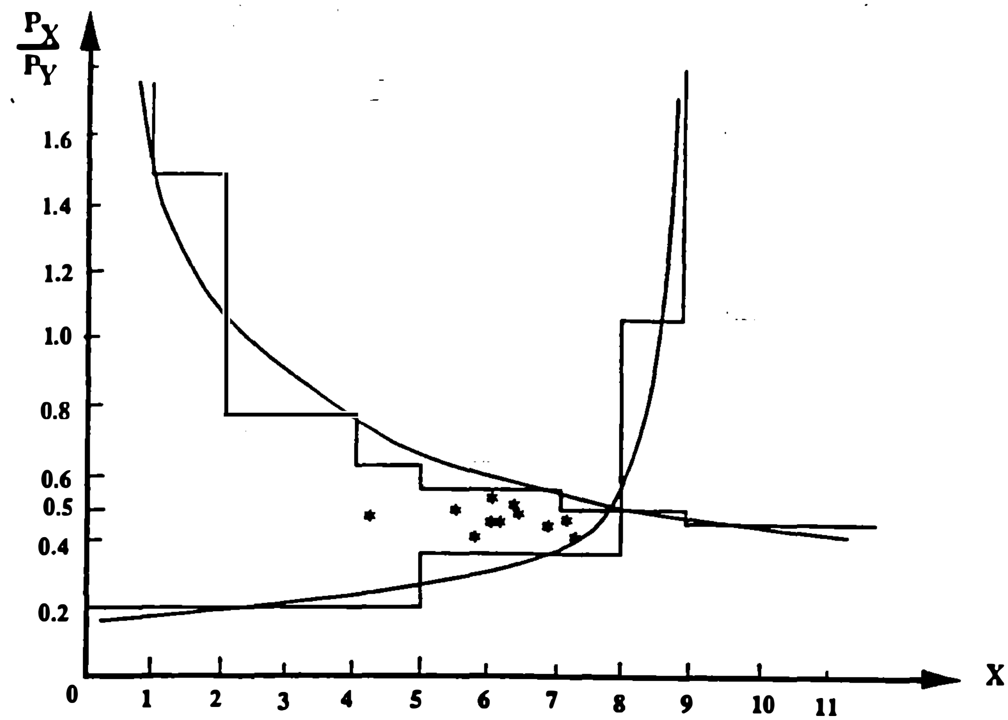


Figure 5a: Actual vs. Theoretical X in Early Periods

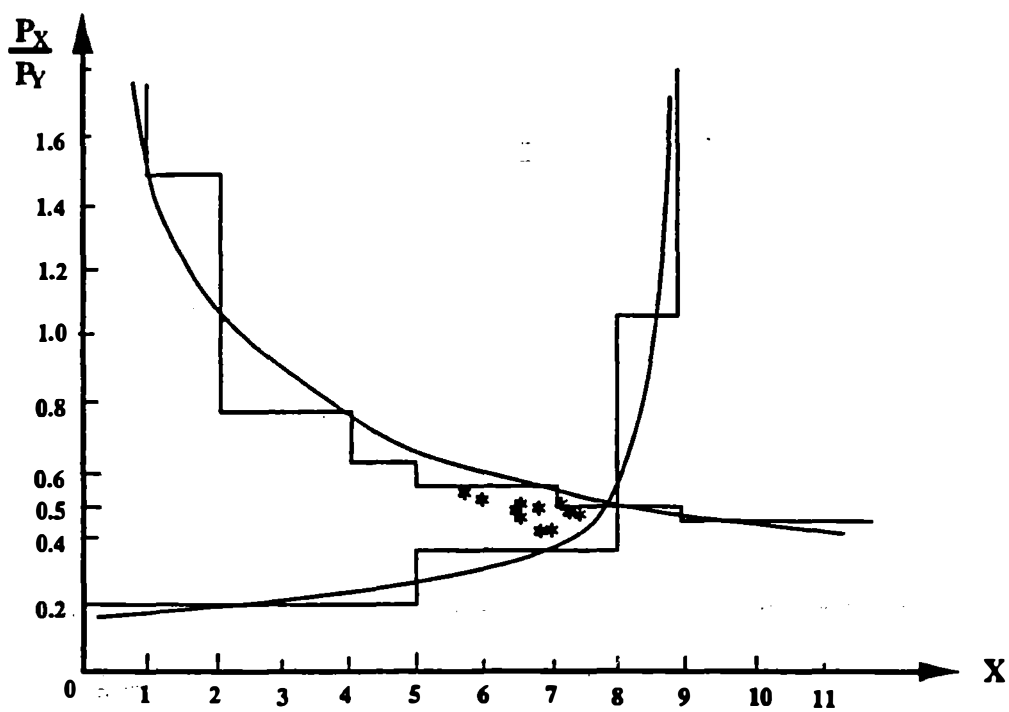


Figure 5b:Actual vs. Theoretical X in Late Periods

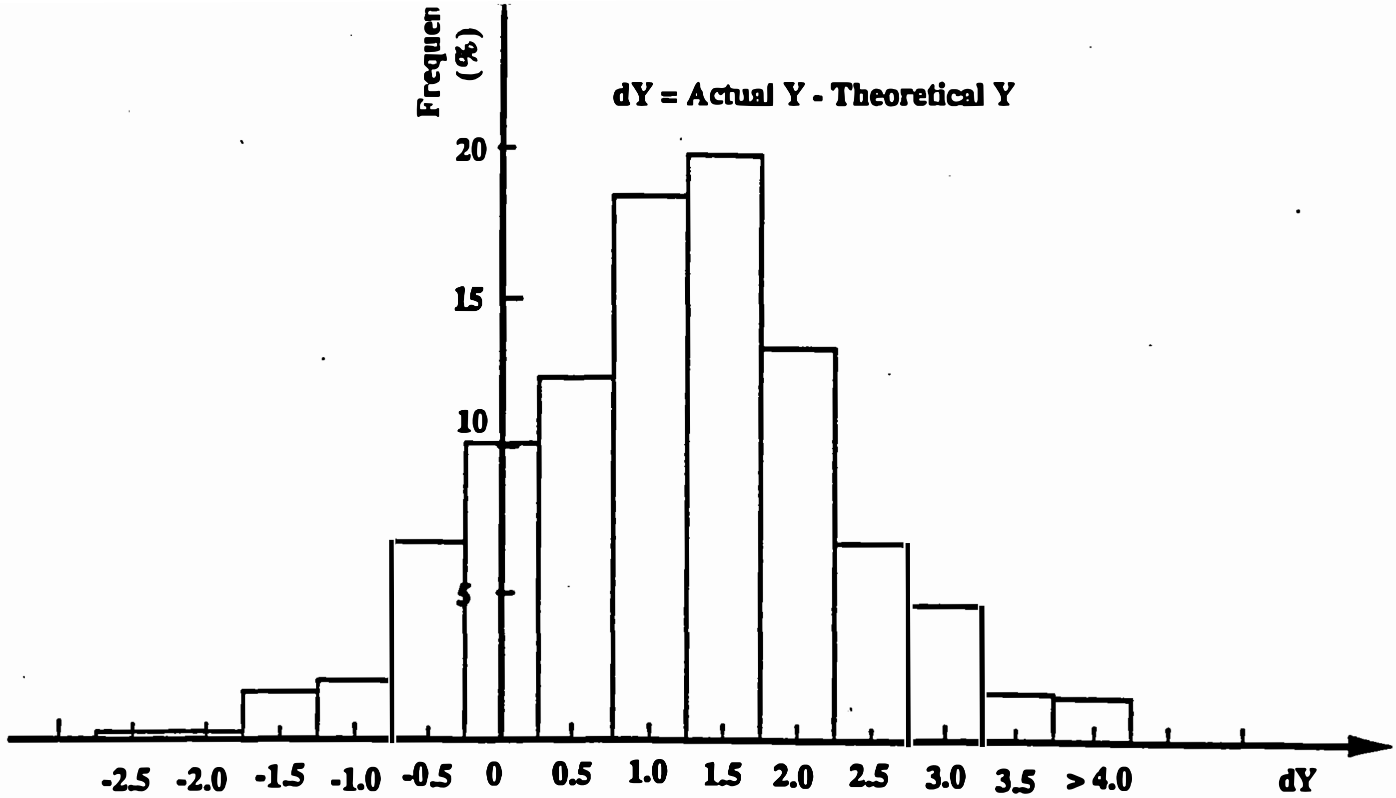


Figure 6a: Frequency Distribution of Overconsumption of Consumers in Early Periods.

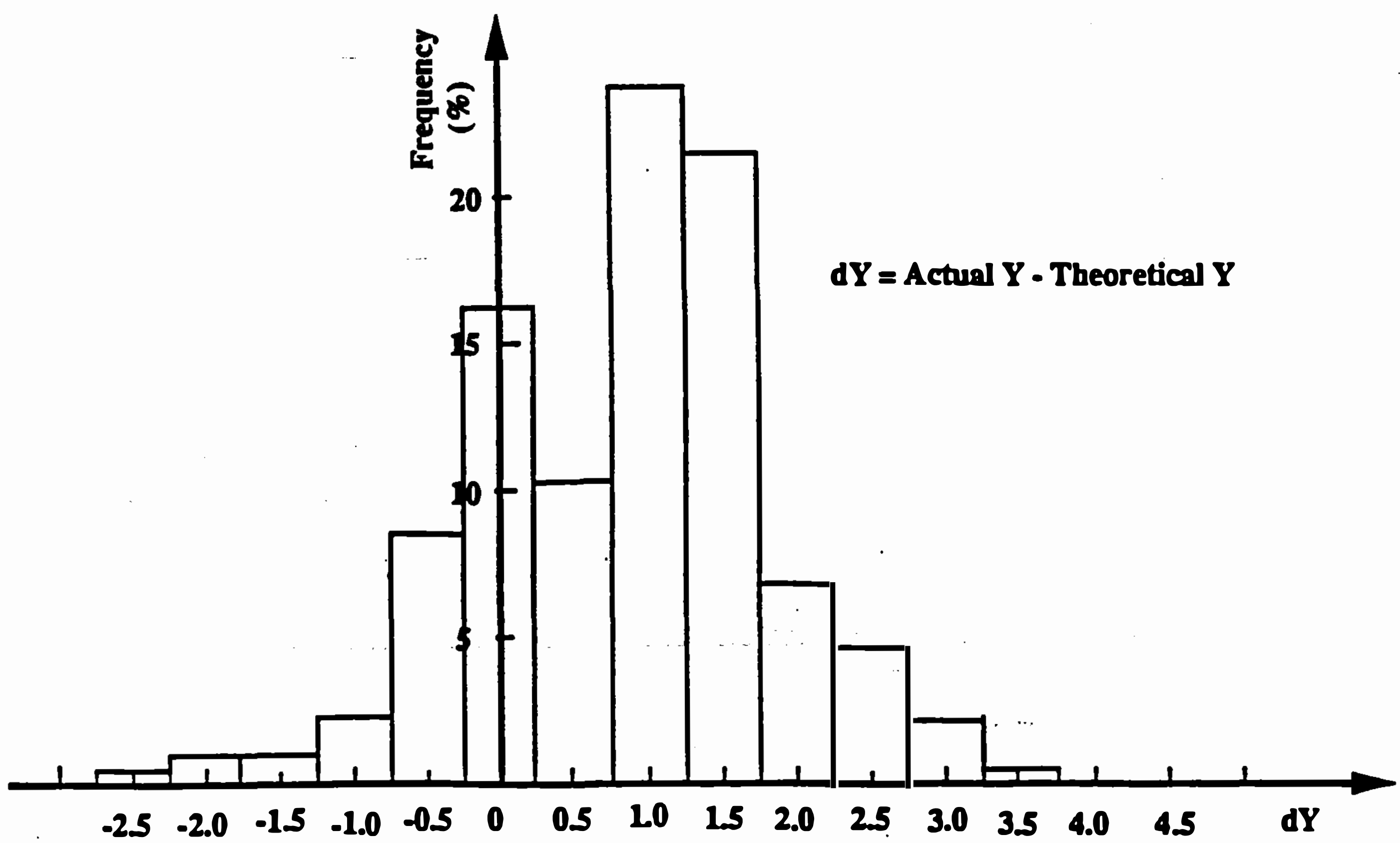


Figure 6b: Frequency Distribution of Overconsumption of Consumers in Late Periods.

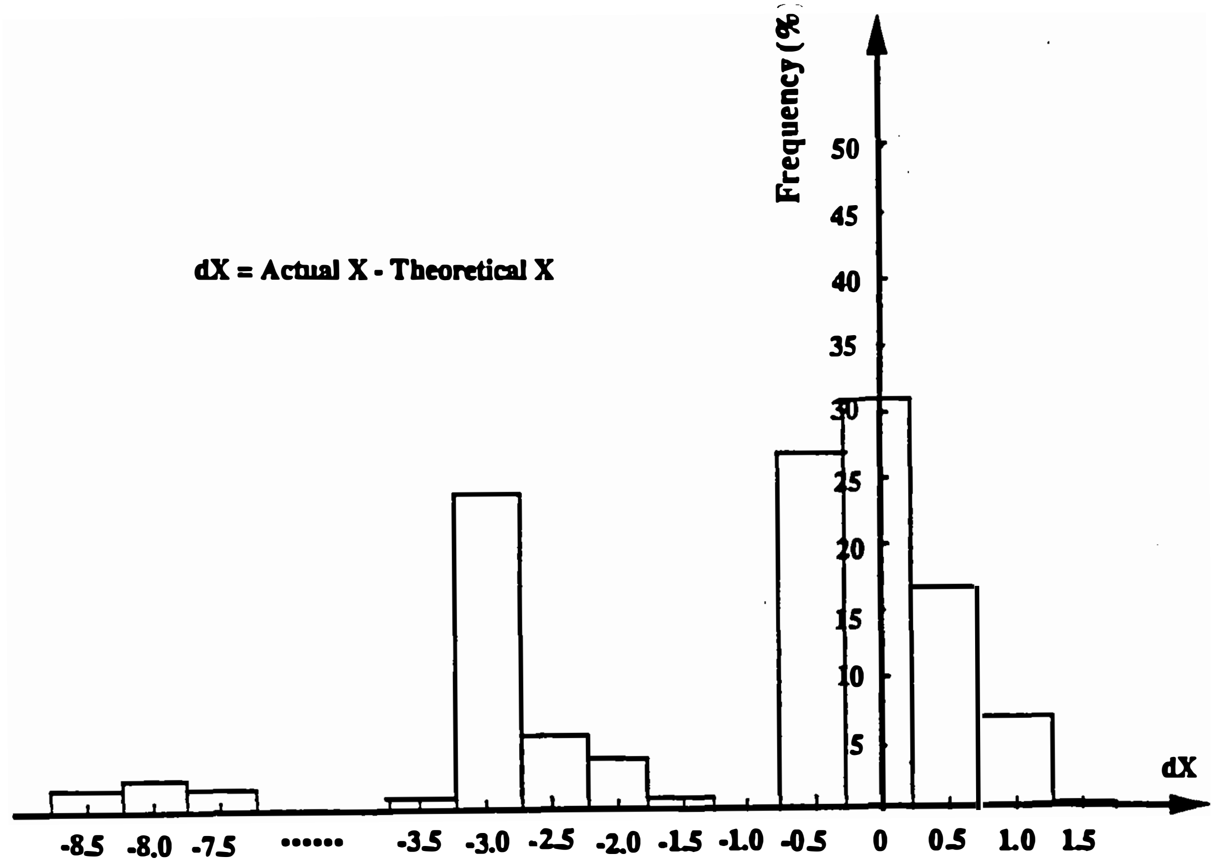


Figure 7a: Frequency Distribution of Underproduction of X in Early Periods.

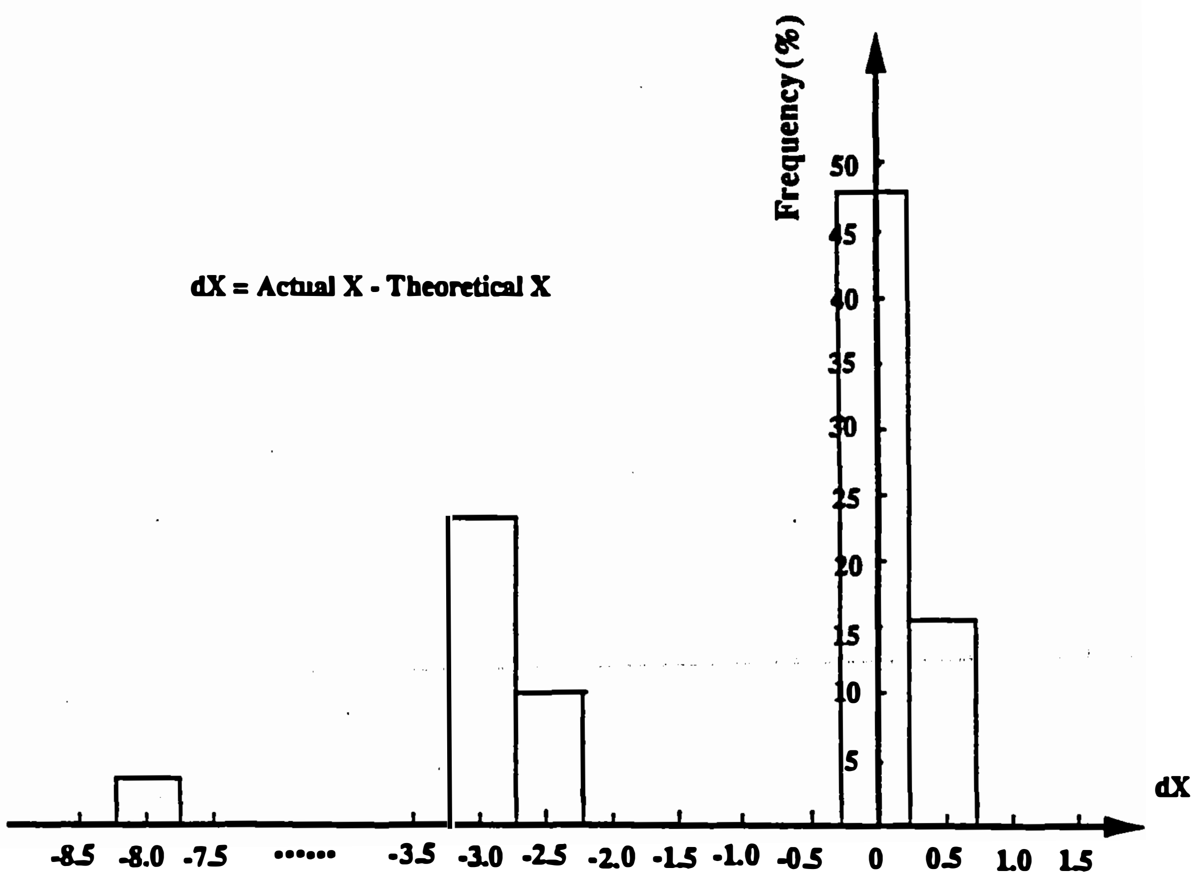


Figure 7b: Frequency Distribution of Underproduction of X in Late Periods.

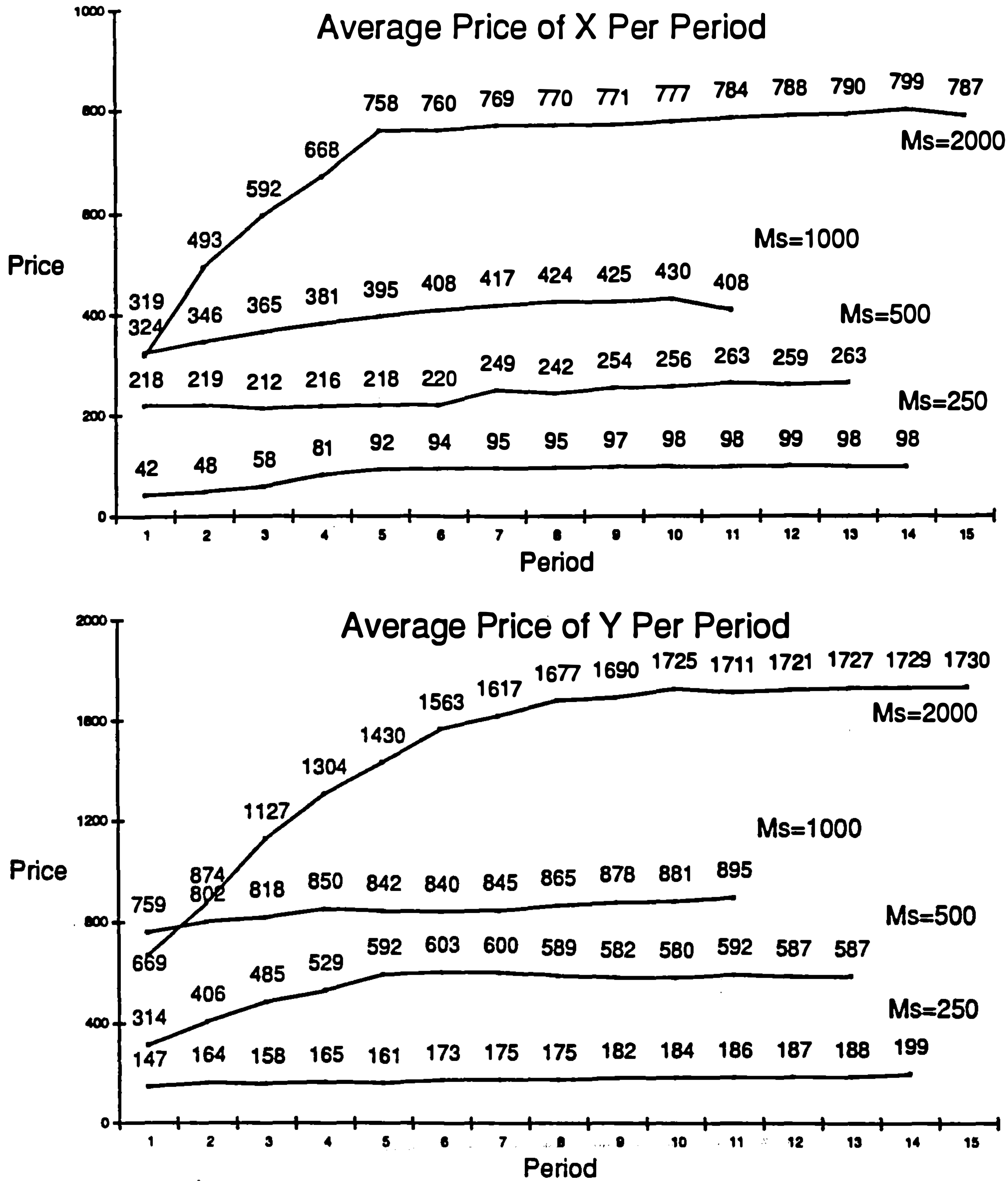


Figure 8:Money Supply and Price Level

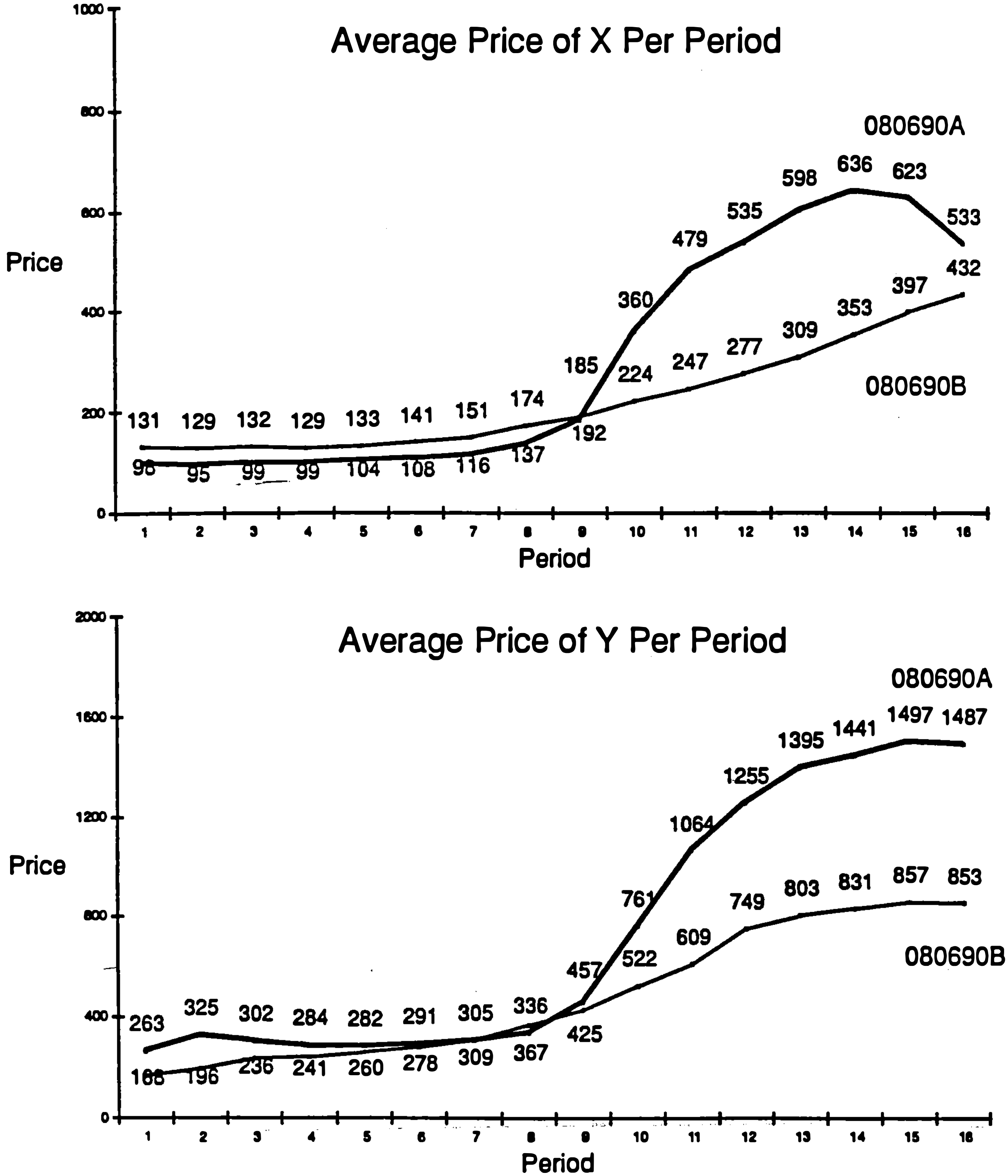


Figure 9: Average Prices Per Period in Series 3